3/07

1.2

## HRS DOCUMENTATION RECORD – REVIEW COVER SHEET

Name of Site: Formosa Mine (Silver Butte Mine, Silver Peak Mine)

Contact Persons:

Site Investigations:

Dynamac Corporation, February 2000, *Final Site Assessment Report, Formosa Mine Site, Douglas County, Oregon.*

Roseburg District, Bureau of Land Management and Oregon Department of Environmental Quality, June 2, 2000, *Formosa Abandoned Mine Land Site Remedial Investigation*

Hart Crowser, Inc., September 21, 2000, *Removal Assessment: Focused Engineering Evaluation and Cost Analysis, Formosa Abandoned Mine Land Site, Douglas County, Oregon.*

Hart Crowser, Inc., December 11, 2004 *Supplemental Remedial Investigation Report, Formosa Abandoned Mine Land Site, Douglas County, Oregon.*

Lynch, Erin, September 18, 2006, Removal Project Manager, Ecology & Environment Inc., memorandum regarding removal assessment activities to date to Renee Nordeen, Project Manager, Ecology & Environment Inc.

Documentation Record:

Renee Nordeen, Ecology & Environment Inc., Seattle, WA

Linda Costello, Ecology & Environment Inc., Seattle, WA

Denise Baker-Kircher, U.S. Environmental Protection Agency, Seattle, WA

Pathways, Components, or Threats Not Scored

The ground water migration pathway, ground water-to-surface water component of the surface water migration pathway, the drinking water threat of the surface water migration pathway, soil exposure pathway, and air migration pathway were not scored as part of this Hazard Ranking System (HRS) evaluation. These pathways/components were not included because a release to these media does not significantly affect the overall site score and because the overland flow/flood component of the surface water migration pathway produces an overall site score well above the minimum required for the site to qualify for inclusion on the National Priorities List. These pathways are of concern to the U.S. Environmental Protection Agency (EPA) and may be evaluated during future investigations.

The ground water-to-surface water component score of the surface water migration pathway was not presented because the overland flow/flood component of the surface water migration pathway generated a higher score. However, the ground water-to-surface water component of the surface water migration pathway is of concern since it is known that contaminated ground water underlying the site is conveying contamination to the adjacent surface water body.

HRS DOCUMENTATION RECORD

Name of Site: Formosa Mine (Silver Butte Mine, Silver Peak Mine)

EPA Region 10 Date Prepared: March 2007

CERCLIS No.: ORN001002616

Street Address of Site[a]: T31 S R 6W Sec 23, Willamette Meridian, Riddle, Oregon 97469

County and State: Douglas County, Oregon (Ref. 12, p. 2-35)

General Location in the State: Southwest

Topographic Map: McCullough Creek, Douglas County, Oregon, 1986.

Latitude: 42° 51' 16.1" North Longitude: 123° 22' 57.4" West (Ref. 3)

| Scores | |
|---|---|
| Ground Water Pathway | NS |
| Surface Water Pathway | 100.00 |
| Soil Exposure Pathway | NS |
| Air Pathway | NS |
| HRS SITE SCORE | 50.00 |

[a] - *The street address, coordinates, and contaminant locations presented in this HRS documentation record identify the general area the site is located. They represent one or more locations EPA considers to be part of the site based on the screening information EPA used to evaluate the site for NPL listing. EPA lists national priorities among the known "releases or threatened releases" of hazardous substances; thus, the focus is on the release, not precisely delineated boundaries. A site is defined as where a hazardous substance has been "deposited, stored, placed, or otherwise come to be located." Generally, HRS scoring and the subsequent listing of a release merely represent the initial determination that a certain area may need to be addressed under the Comprehensive Environmental Response, Compensation, and Liability Act. Accordingly, EPA contemplates that the preliminary description of facility boundaries at the time of scoring will be refined as more information is developed as to where the contamination has come to be located.*

SURFACE WATER OVERLAND FLOW/FLOOD MIGRATION COMPONENTS SCORESHEET

| Factor categories and factors | Maximum Value | Value Assigned | |
|---|---|---|---|
| **Drinking Water Threat** | | | |
| **Likelihood of Release:** | | | |
| 1. Observed Release | 550 | 550 | |
| 2. Potential to Release by Overland Flow: | | | |
| 2a. Containment | 10 | | |
| 2b. Runoff | 25 | | |
| 2c. Distance to Surface Water | 25 | | |
| 2d. Potential to Release by Overland Flow [lines 2a(2b + 2c)] | 500 | | |
| 3.Potential to Release by Flood: | | | |
| 3a. Containment (Flood) | 10 | | |
| 3b. Flood Frequency | 50 | | |
| 3c. Potential to Release by Flood (lines 3a x 3b) | 500 | | |
| 4. Potential to Release (lines 2d + 3c, subject to a maximum of 500) | 500 | | |
| 5. Likelihood of Release (higher of lines 1 and 4) | 550 | | 550 |
| **Waste Characteristics:** | | | |
| 6. Toxicity/Persistence | (a) | | |
| 7. Hazardous Waste Quantity | (a) | | |
| 8. Waste Characteristics | 100 | | 0 |
| **Targets:** | | | |
| 9. Nearest Intake | 50 | | |
| 10. Population: | | | |
| 10a. Level I Concentrations | (b) | | |
| 10b. Level II Concentrations | (b) | | |
| 10c. Potential Contamination | (b) | | |
| 10d. Population (lines 10a + 10b + 10c) | (b) | | |
| 11. Resources | 5 | | |
| 12. Targets (lines 9 + 10d + 11) | (b) | | |
| **Drinking Water Threat Score:** | | | |
| 13. Drinking Water Threat Score [(lines 5x8x12)/82,500, subject to a maximum of 100] | 100 | | 0 |
| **Human Food Chain Threat** | | | |
| **Likelihood of Release:** | | | |
| 14. Likelihood of Release (same value as line 5) | 550 | | 550 |
| **Waste Characteristics:** | | | |
| 15. Toxicity/Persistence/Bioaccumulation | (a) | $5X10^8$ | |
| 16. Hazardous Waste Quantity | (a) | 10,000 | |
| 17. Waste Characteristics | 1,000 | | 1,000 |
| **Targets:** | | | |
| 18. Food Chain Individual | 50 | 45 | |
| 19. Population | | | |
| 19a. Level I Concentration | (b) | 0 | |
| 19b. Level II Concentration | (b) | 0.03 | |
| 19c. Potential Human Food Chain Contamination | (b) | 0.00003 | |
| 19d. Population (lines 19a + 19b + 19c) | (b) | 0.03003 | |
| 20. Targets (lines 18 + 19d) | (b) | | 45.03003 |
| **Human Food Chain Threat Score:** | | | |
| 21. Human Food Chain Threat Score [(lines 14x17x20)/82500, subject to maximum of 100] | 100 | | 100 |

SURFACE WATER OVERLAND FLOW/FLOOD MIGRATION COMPONENTS SCORESHEET

| Environmental Threat | | | |
|---|---|---|---|
| **Likelihood of Release:** | | | |
| 22. Likelihood of Release (same value as line 5) | 550 | | 550 |
| **Waste Characteristics:** | | | |
| 23. Ecosystem Toxicity/Persistence/Bioaccumulation | (a) | $5X10^8$ | |
| 24. Hazardous Waste Quantity | (a) | 10,000 | |
| 25. Waste Characteristics | 1,000 | | 1,000 |
| **Targets:** | | | |
| 26. Sensitive Environments | | | |
| 26a. Level I Concentrations | (b) | 0 | |
| 26b. Level II Concentrations | (b) | 75 | |
| 26c. Potential Contamination | (b) | 0 | |
| 26d. Sensitive Environments (lines 26a + 26b + 26c) | (b) | 75 | |
| 27. Targets (value from line 26d) | (b) | | 75 |
| **Environmental Threat Score:** | | | |
| 28. Environmental Threat Score [(lines 22x25x27)/82,500 subject to a maximum of 60] | 60 | | 60 |
| **Surface Water Overland/Flood Migration Component Score for a Watershed** | | | |
| 29. Watershed Score[c] (lines 13+21+28, subject to a maximum of 100) | 100 | | 100 |
| **Surface Water Overland/Flood Migration Component Score** | | | |
| 30. Component Score ($S_{sw}$)[c] (highest score from line 29 for all watersheds evaluated, subject to a maximum of 100) | 100 | | 100 |
| [a] Maximum value applies to waste characteristics category<br>[b] Maximum value not applicable<br>[c] Do not round to nearest integer | | | |

WORKSHEET FOR COMPUTING HRS SITE SCORE

| | S pathway | $S^2$ pathway |
|---|---|---|
| Ground Water Migration Pathway Score ($S_{gw}$) | NS | NS |
| Surface Water Migration Pathway Score ($S_{sw}$) | 100 | 10,000 |
| Soil Exposure Pathway Score ($S_s$) | NS | NS |
| Air Migration Score ($S_a$) | NS | NS |
| $S^2_{gw} + S^2_{sw} + S^2_s + S^2_a$ | | 10,000 |
| $(S^2_{gw} + S^2_{sw} + S^2_s + S^2_a)/4$ | | 2,500 |
| $\sqrt{(S^2_{gw} + S^2_{sw} + S^2_s + S^2_a)/4}$ | | 50.00 |

Note:
NS = Not scored.

## REFERENCES


| Reference Number | Description of the Reference |
|---|---|
| 1. | U.S. Environmental Protection Agency (EPA), December 14, 1990, Hazard Ranking System, Final Rule, 40 CFR Part 300, Appendix A, 55 FR 51532, 4 pages. |
| 2. | U.S. EPA, January 2004, Superfund Chemical Data Matrix, 11 pages. |
| 3. | U.S. Geological Survey, 1986, 7.5 x 15-Minute topographic map, McCullough Creek, Douglas County, Oregon, 1 page. |
| 4. | Hart Crowser, Inc., December 11, 2002, *Supplemental Remedial Investigation Report, Formosa Abandoned Mine Land Site, Douglas County, Oregon*, prepared for Oregon Department of Environmental Quality, Task Order No. 89-97-32 Volume I – 225 pages, Volume II – 490 pages. |
| 5. | The Roseburg District, Bureau of Land Management and the Oregon Department of Environmental Quality, June 2, 2000, *Formosa Abandoned Mine Land Site Remedial Investigation*, 69 pages. |
| 6. | Dynamac Corporation, February 2000. *Final Site Assessment Report, Formosa Mine Site, Douglas County, Oregon*, prepared for U.S. Department of the Interior Bureau of Land Management, Roseburg Oregon District, Work Assignment No. BLM2-30R, 204 pages. |
| 7. | Hart Crowser, Inc., November 8, 2001, *Supplemental Remedial Investigation Work Plan, Formosa Abandoned Mine Land Site, Douglas County, Oregon*, prepared for Oregon Department of Environmental Quality, 91 pages. |
| 8. | Throop, Allen H., Oregon Department of Geology and Mineral Industries, *Reclamation of Formosa Exploration's Silver Butte Mine as of December 1994*, 25 pages. |
| 9. | Hart Crowser, Inc., September 21, 2000, *Removal Assessment: Focused Engineering Evaluation and Cost Analysis, Formosa Abandoned Mine Land Site, Douglas County, Oregon*, prepared for Oregon Department of Environmental Quality, Task Order No. 89-97-25, 255 pages. |
| 10. | Dynamac Corporation, September 30, 1999, *Draft Sampling and Analysis Plan for the Environmental Site Assessment Silver Butte and Umpqua Mine Sites Oregon*, prepared for U.S. Department of the Interior Bureau of Land Management, Roseburg Oregon District, 75 pages. |
| 11. | Ecology and Environment, Inc., June 21, 2006, *Formosa Mine Site Site-Specific Sampling Plan*, TDD: 06-01-0025, 141 pages. |
| 12. | Ecology and Environment, Inc., March 2006, *Formosa Mine Preliminary Assessment Report*, TDD: 06-01-0033, 59 pages. |
| 13. | United States Geologic Survey, September 26, 2005, *Calendar Year Streamflow Statistics for the Nation, USGS 14310000 Cow Creek near Riddle, OR*, 1 page. |
| 14. | Lynch, Erin, Project Manager, Ecology and Environment, Inc., September 18, 2006, memorandum subject: Formosa Mine, Douglas County, Oregon Removal Assessment Activities to Date, to Renee Nordeen, Project Manager, Ecology and Environment Inc., 100 pages. |
| 15. | Carr, Fabian, Fish Biologist, Oregon Department of Fish and Wildlife, October 25, 2006, telephone conversation regarding: fishing occurrence in Middle Creek, South Fork Middle Creek, and Cow Creek, with Kerrie Stewart, Ecology and Environment Inc., 2 pages. |
| 16. | Roseburg District Bureau of Land Management, Oregon Department of Environmental Quality, June 15, 1999 through March 23, 2000, Formosa Mine Surface Water Analytical Laboratory Reports and chain-of-custody reports, with data validation memoranda from Mark Woodke, START-3 Chemist, Ecology & Environment Inc. includes data collected in support of *Formosa Abandoned Mine Land Site Remedial Investigation* dated June 2, |

## REFERENCES


| Reference Number | Description of the Reference |
|---|---|
| | 2000 (Reference 5), 179 pages. |
| 17. | Oregon Department of Geology and Mineral Industries, November 1989 (refer to page 7), *Evaluation Description, Formosa Exploration, Inc., Operating Permit for the Silver Peak Mine, Douglas County, Oregon, I.D. #10-0195,* 12 pages. |
| 18. | Brick, Jim, Fish Biologist, Oregon Department of Fish and Wildlife, March 31, 2005, telephone conversation regarding threatened and endangered species in South Fork Middle Creek and Middle Creek with Kerrie M. Stewart, Ecology & Environment Inc., 1 page. |
| 19. | Hart Crowser, Inc., January 15, 2004, *Human Health and Ecological Baseline Risk Assessment, Formosa Abandoned Mine Land Site, Douglas County, Oregon*, prepared for Oregon Department of Environmental Quality, Task Order No. 73-03-7, 297 pages. |
| 20. | Harvey, Jim, Roseburg BLM, October 13, 2006, Formosa Mine Sampling Locations: Water Quality Site Locations for Samples Collected March 21-23, 2000, Renee Nordeen, Ecology & Environment Inc., 1 page. |
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| 22. | U.S. Bureau of Land Management, November 2002, *Lower Cow Creek Watershed Analysis and Water Quality Restoration Plan, Roseburg District South River Resource Area*, Second iteration, 410 pages. |
| 23. | Oregon Department of Environmental Quality, Laboratory Division, Biological Monitoring Section, June 23, 1998, *Field Methods, Oregon Plan for Salmon and Watersheds, (Coastal Salmon Restoration Initiative), Physical Habitat, Macroinvertebrates, Aquatic Vertebrates, Water Chemistry,* Version 1.0, 101 pages. |
| 24. | Oregon Department of Fish and Wildlife, July 11 through 17, 1969, Oregon State Game Commission, Physical and Biological Stream Survey field data, 25 pages. |
| 25. | U.S. Bureau of Land Management, Roseburg District, 1982 and 1984, Franklin Oliver's field notes from sampling conducted, 8 pages. |
| 26. | NORECOL, December 1, 1988, *Formosa Exploration, Inc., Fisheries, Water Quality and Hydrology Trip Report, October 4 – 6, 1988*, 6 pages. |
| 27. | U.S. Bureau of Land Management, Roseburg Office, July 17 – 21, 2000, Results of BLM field sampling, 2 pages. |
| 28. | U.S. Bureau of Land Management, Roseburg Office, August 11, 2003, Formosa AML Sampling Protocols and Field Notes, 16 pages. |
| 29. | Oregon Department of Fish and Wildlife, 2006, *Oregon Sport Fishing 2006 Regulations*, 3 pages. |
| 30. | Throop, Allen H., Oregon Department of Geology and Mineral Industries, April 1996, *Formosa Exploration's Silver Butte Mine Status Update – April 1996*, 5 pages. |
| 31. | Frerichs, Don, Game Officer, Oregon State Police, October 26, 2006, telephone conversation regarding: fish catch/release and consumption information for Cow Creek and related tributaries (Middle Creek and South Fork Middle Creek), with Kerrie Stewart, Ecology & Environment Inc., 1 page. |
| 32. | Columbia River Inter-Tribal Fish Commission, Winter 2003, *Wana Chinook Tymoo*, 44 pages. |
| 33. | Robert Neely, Regional Resource Coordinator, National Oceanic and Atmospheric Administration, January 18, 2007, letter to Ms. Denise Baker, US EPA Region 10 regarding recommendation on Formosa Abandoned Mine Land Site for EPA Regional Decision Team, 7 pages. |

## REFERENCES


| Reference Number | Description of the Reference |
|---|---|
| 34 | Western Regional Climate Summary, January 15, 2007, Period of Record Monthly Climate Summary Riddle 2 NNE Oregon, 357169, 1 page. |
| 35. | Hart Crowser, Inc., March 22, 2001, *Interim Remedial Action Measure Report, Formosa Abandoned Mine Land Site, Douglas County, Oregon*, pre pared for Oregon Department of Environmental Quality, Task Order No. 89-97-25, 37 pages. |
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| 37. | Screen shot of conversion program demonstrating conversion from cubic feet per second to gallons per second, 1 page. |
| 38. | Oregon Department of Fish and Wildlife, Salmon/Steelhead Tags – Oregon All Tags Sport Catch for 1994, 53 pages. |
| 39. | Showers, April, Ecology and Environment, Inc., January 23, 2007, memorandum to Renee Nordeen, Project Manager, Ecology and Environment, Inc., regarding calculation of distances, Formosa Mine, Douglas County, 4 pages. |
| 40. | Woodke, Mark, Chemist, Ecology and Environment, Inc., January 22, 2007, memorandum to Renee Nordeen, Project Manager, Ecology and Environment, Inc., regarding inorganic data summary check, Formosa Mine Final Site Assessment Report site, Douglas County, Oregon, 26 pages. |
| 41. | Woodke, Mark, Chemist, Ecology and Environment, Inc., January 22, 2007, memorandum to Renee Nordeen, Project Manager, Ecology and Environment, Inc., regarding inorganic data summary check Formosa Mine Supplemental Remedial Investigation Report, Douglas County, Oregon, 28 pages. |
| 42. | United States Environmental Protection Agency, November 1996, *Using Qualified Data to Document an Observed Release and Observed Contamination*, EPA 540-F-94-028, OSWER 9285.7-14FS PB94-963311, 18 pages. |
| 43. | James Harvey, US BLM. February 15, 2007. email supporting the presence of perennial streams in the vicinity of Formosa Mine. |

SITE SUMMARY:

The Formosa Mine site has also been referred to as the Silver Butte Mine, the Silver Peak Mine, and the Formosa Abandoned Mine Land Site (Ref. 4, pp. 6, 55; Ref. 5, pp. 7, 8; Ref. 6, p. 2). The site will be referred to as the Formosa Mine in this documentation record. The Formosa Mine is located in the South Umpqua watershed, approximately 25 miles south of Roseburg, Oregon (Ref. 5, p. 7). Four creeks have their headwaters near the Formosa Mine: Middle Creek, South Fork Middle, Russell Creek, and West Fork Canyon Creek (Ref. 4, p. 8). Of these, Middle Creek and South Fork Middle Creek have been impacted by the Formosa Mine (Ref. 4, p. 6). Mining activity at the Formosa Mine began in the early 1900s and has included explorations and commercial workings for copper, gold, silver, and zinc (Ref. 5, p. 7). The Formosa Mine was first explored in 1910 (Ref. 17, p. 1). The primary operation of the mine occurred from 1927 to 1933, and from 1990 to 1993 (Ref. 4, p. 8). Between 1920 and 1930, over 6,000 tons of ore were mined for copper, gold, and silver (Ref. 17, p. 1). There are no records of any reclamation activities prior to 1993 (Ref. 4, p. 10). The main features at the site are three adits (Formosa 1, Silver Butte, and the 404), the former mill site, a tailings and water storage pond (now referred to as the encapsulation mound), and waste rock piles (Figure 1; Ref. 4, p. 8; Ref. 6, p. ES-1; Ref. 8, pp. 14, 15).

Formosa Explorations, Inc. began exploration of the Formosa Mine in the mid-1980s, received an operating permit in 1989, and the mill began production and underground mine operations in 1990, producing copper and zinc at a rate of 350 to 400 tons per day (Ref. 6, p. ES-1; Ref. 8, p. 8; Ref. 9, p. 1). The operating permit required a $500,000 bond prior to commencement of mining activities due to the anticipated high cost of reclamation at mine closure (Ref. 17, p. 6). Formosa Explorations erected a mill and an associated tailings and water storage pond on a ridge approximately ¼ mile south of the Formosa 1 Adit (Ref. 8, p. 14). The mill was capable of processing 200 tons of ore per day through a crusher located at the Formosa 1 Adit (Ref. 8, p. 14).

Mining permanently ceased at the Formosa Mine on August 1, 1993 after Formosa Exploration received a Closure Order from Oregon Department of Geology and Mineral Industries (DOGAMI) and a Notice of Noncompliance from the Oregon Department of Environmental Quality (Ref. 8, p. 2; Ref. 6, p. 8; Ref. 22, p. 18). Upon closure of the mine in 1994, DOGAMI required Formosa to conduct mine reclamation activities (Ref. 9, p. 5). Formosa Explorations backfilled the mine workings with processed, high-grade ore as part of an initial remedial effort (Ref. 4, p. 8; Ref. 6, p. ES-1). All the known adits were sealed to at least some degree by Formosa Explorations (Ref. 6, p. ES-1). Under the supervision of the United States Bureau of Land Management (BLM) and the DOGAMI, Formosa Explorations constructed a drainage system to capture the adit discharge and carry the discharge via a pipeline for discharge on private lands; however, this system has had numerous problems since its installation, and water bypasses the system and has resulted in continued impacts (Ref. 6, p. ES-1). The mine workings (including the backfilled high-grade ore) are a source of acid mine drainage (Ref. 4, pp. 8, 9).

By January 14, 1994, the crusher and its foundation had been removed from its location next to the Formosa 1 Adit (Ref. 8, p. 14). The mill building and its equipment were sold and removed from the mine in May and June 1995 (Ref. 8, p. 14). After removal of the mill building, the foundation was washed clean of sulfides (Ref. 8, p. 14).

The tailings and water storage pond was backfilled with low-grade ore (Ref. 8, p. 15). After backfilling, the pond was covered with a Bentomat cover (a woven fabric with natural bentonite

embedded in it at a uniform thickness) then soil was placed over the cover at a minimum thickness of 4.2 feet and an average thickness of approximately 7.25 feet (Ref. 8, p. 16). After this process was complete, the backfilled pond became known at the encapsulation mound (Ref. 6, p. ES-1).

The EPA has not conducted a site investigation (SI) at the Formosa Mine; however, several privately funded investigations have been conducted. Additionally, an EPA-funded removal assessment is being conducted at the mine. The following investigations will be used to document the presence of hazardous substances in both sources and targets:

**Final Site Assessment (Ref. 6)**: The site assessment was conducted from October 19 to 25, 1999 by Dynamac Corporation for the BLM (Ref. 6, p. ES-1). The objectives of this investigation were to 1) identify and characterize the nature and extent of environmental contamination at the Formosa Mine; 2) quantify, to the extent possible, the damage caused to the quality of the surrounding environmental media (i.e., surface water, ground water, and soil) and local flora and fauna as a result of the mining activities; 3) evaluate the potential for off-site impacts to human health and the environment; and 4) collect information necessary to make generalized recommendations regarding future activities at the Formosa Mine (Ref. 6, p. ES-1). As a result of this investigation, the report concluded the following: the analytical results of every type of media sampled suggest that heavy metal contamination from the Formosa Mine continues to affect the surrounding media (Ref. 6, p. 53). Further, waste source piles laden with heavy metals remain uncontained, and are susceptible to storm flooding and erosion (Ref. 6, p. 53). Consequently, metals have mobilized and been transported to surrounding soils and surface waters, particularly Middle Creek (Ref. 6, p. 53). Finally, metal loading calculations for the Formosa Adit, backfilled with waste materials, and associated drain line appear to show significant impacts to water quality on the surface (Ref. 6, p. 53).

**Remedial Investigation (Ref. 5):** The remedial investigation was conducted in June 1999 by the Roseburg District BLM, and the Oregon Department of Environmental Quality (ODEQ) in response to an observed decline in biological conditions since the closure of the Formosa Mine in 1993 (Ref. 5, p. 9). The objectives of this investigation were to: 1) determine if adjacent drinking water supplies were being affected by the Formosa Mine related contamination; 2) characterize current biological conditions relative to previous data; 3) quantify the spatial and seasonal impacts of Formosa Mine contaminants to aquatic life uses; 4) characterize the spatial and seasonal severity and extent of downstream contaminant transport; 5) broadly identify contaminant sources; and 6) gather water quality and biological information necessary for the design of successful remedial actions (Ref. 5, p. 9, 10). The summary of findings for the remedial investigation concluded the following:

- Some of the primary sources of contamination to the Middle Creek and South Fork Middle Creek streamsheds are:
    - Surface discharges from the Formosa 1 and Silver Butte Adits;
    - Leachates from the encapsulation mound located at the headwaters of the South Fork of Middle Creek;
    - The primary mechanism of contaminant mobilization and transport is tied to storm events and precipitation patterns (Ref. 5, p. 2)
- State designated beneficial uses adversely affected by Formosa Mine effluents were primarily limited to freshwater fish and aquatic life (Ref. 5, p. 2).
- Aquatic insect data collected on Middle Creek and the South Fork Middle Creek from 1982 to 1999 indicate that biological conditions have degraded since the closure of the Formosa Mine in 1993 (Ref. 5, p. 2).

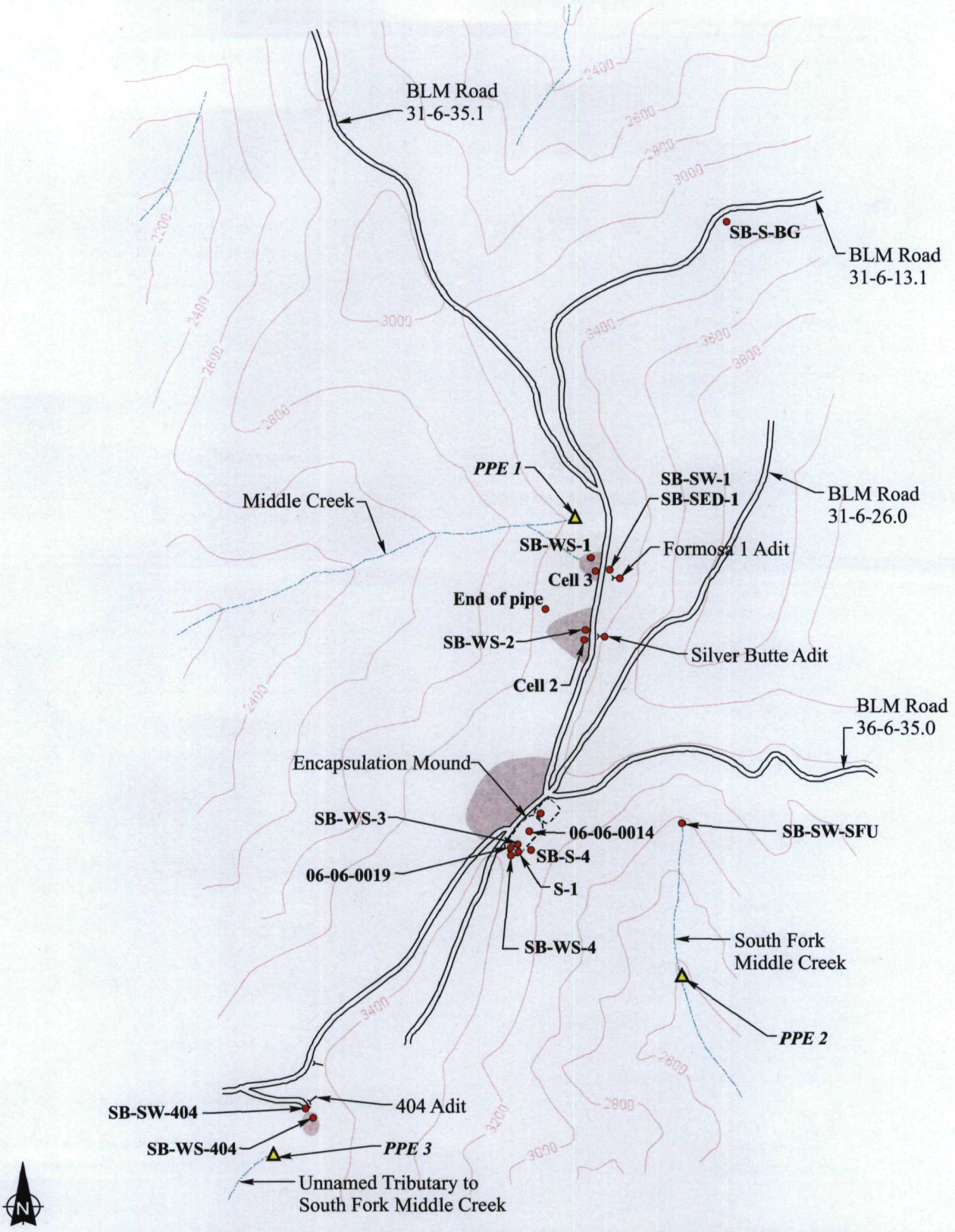
- Stream surveys conducted in 1982 and 1989 found juvenile coho salmon, steelhead, and cutthroat trout throughout most of Middle Creek and the South Fork of Middle Creek (Ref. 5, p. 3). The observed metals concentrations in Middle Creek and the South Fork of Middle Creek, would be expected to either be chronically toxic to salmonids, and/or limit populations due to lack of food organisms (Ref. 5, p. 3)

**Supplemental Remedial Investigation (Ref. 4):** Data collection for the supplemental remedial investigation was conducted from November 2001 through May 2002 by Hart Crowser, Inc., for ODEQ (Ref. 4, pp. 1, 6, 7). The purpose of the remedial investigation was to supplement the remedial investigation that was conducted by the BLM and to better define sources and transport pathways by collecting and analyzing ground water, precipitate/sediment, surface water, and soil samples (Ref. 4, p. 7). This investigation concluded that the primary sources of metals in both Middle Creek and South Fork Middle Creek are the mine workings (Ref. 4, p. 28). The other sources (e.g., the encapsulation mound and waste rock) are likely one to two orders of magnitude less than the mine working (although, in the absence of the mine workings, these sources may have local impacts to water quality) (Ref. 4, p, 28).

**Removal Assessment (Ref. 14):** The EPA-funded removal assessment is currently being conducted by Ecology & Environment Inc. The field sampling event was conducted In June and July 2006 (Ref. 14, p. 1). The objectives of the removal assessment are to conduct limited sampling and focus on providing removal option recommendations by identifying areas of concern; filling in data gaps; identifying and evaluating removal options (based on data collected for the removal assessment and data collected in previous studies); estimating costs for identified removal options; and making and prioritizing removal recommendations (Ref. 11, p. 3).

In 2004, it was documented that heavy metals concentrations in Middle Creek and South Fork Middle Creek exceed aquatic life standards by a factor of between 10 and 100, severely degrading habitat for aquatic receptors including macroinvertebrates, coastal steelhead trout, and Oregon coastal Coho salmon (Ref. 21, p. 1). Finally, it has been documented that fishing is occurring on Middle Creek and Cow Creek within the zone of actual contamination (Figures 2 through 4; Ref. 15, p. 1, 2; Ref. 18, p. 1; Ref. 31, p. 1). Discharges from the Formosa Mine probably have been negatively affecting Middle Creek for approximately 80 years (Ref. 22, p. 18).

**Base Map Reference:** Hart Crowser 2002.

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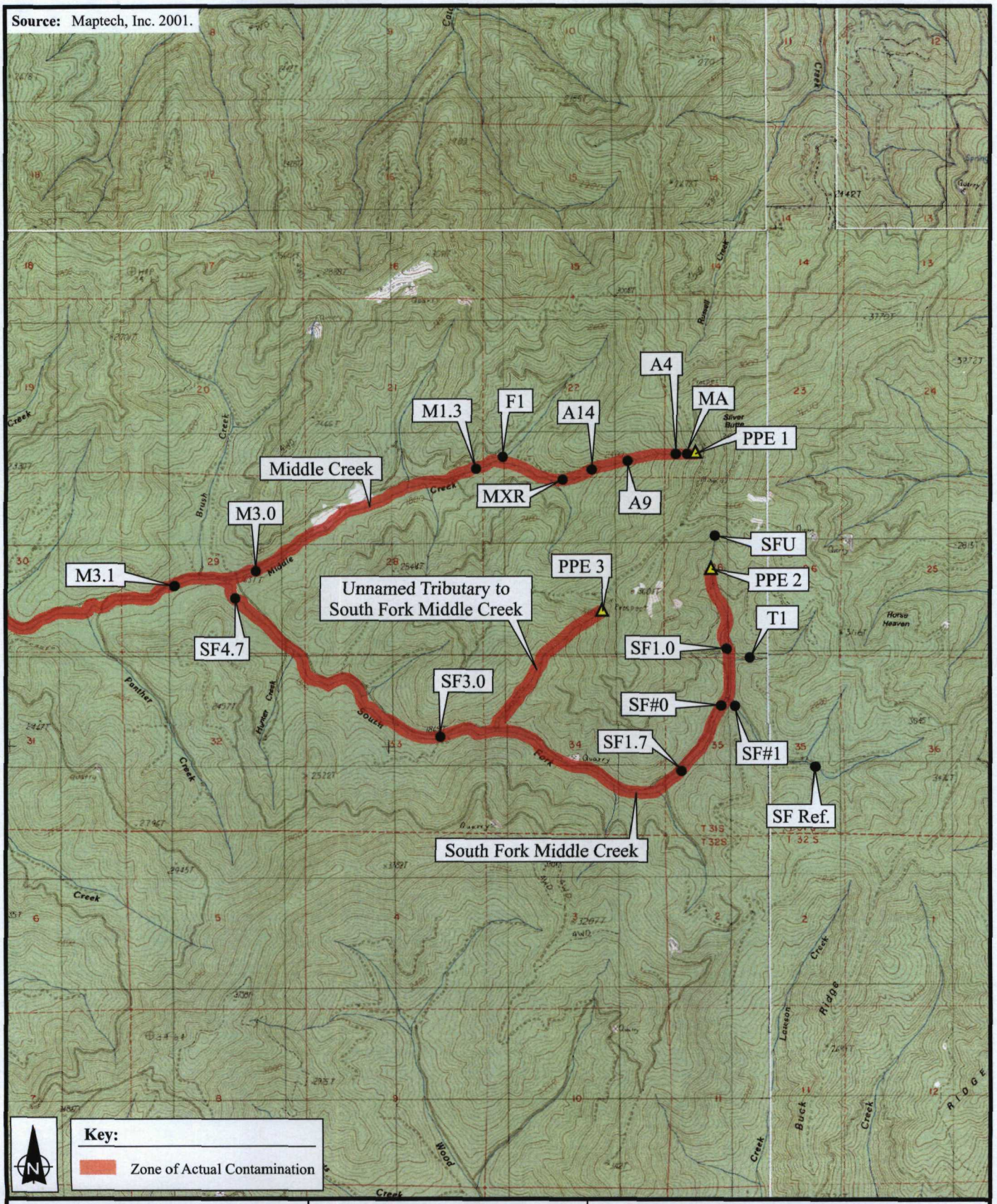
|---|---|---|---|---|
| **ecology and environment, inc.**<br>International Specialists in the Environment<br>Seattle, Washington | FORMOSA MINE SITE<br>Douglas County, Oregon | Figure 1<br>SITE AND PPE MAP | | |
| | 0 500 1000<br>Approximate Scale in Feet | Date:<br>1-24-07 | Drawn by:<br>AES | 10:START-3\06010033\fig 1 |

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| ecology and environment, inc.<br>International Specialists in the Environment<br>Seattle, Washington | FORMOSA MINE<br>PRELIMINARY ASSESSMENT<br>Douglas County, Oregon | Figure 2<br>SOUTH FORK MIDDLE CREEK AND<br>MIDDLE CREEK TO M3.1 | | |
| | 0 2000 4000<br>Approximate Scale in Feet | Date:<br>1-24-07 | Drawn by:<br>AES | 10:START-3\06010033\fig 2 |


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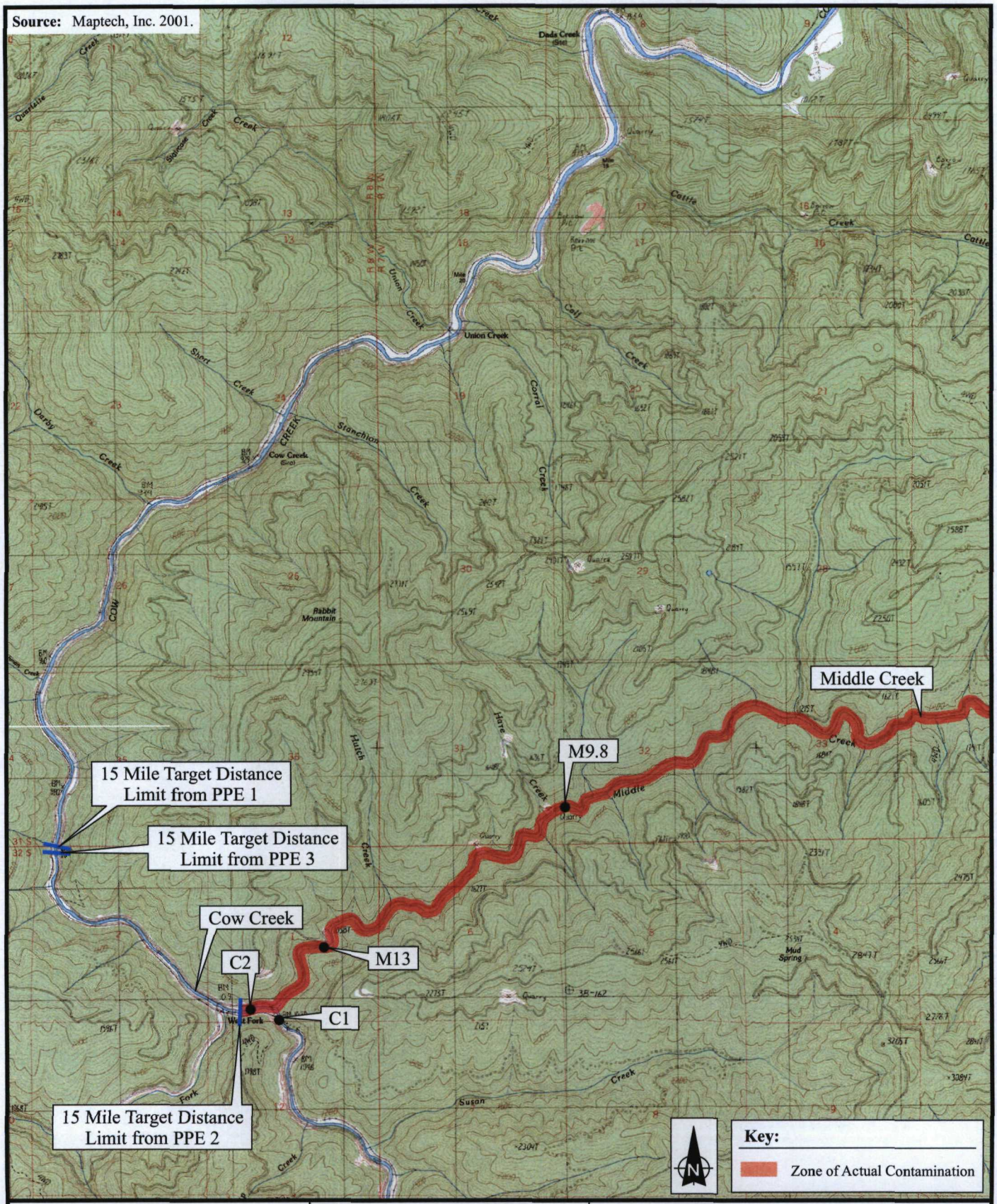
| ecology and environment, inc.<br>International Specialists in the Environment<br>Seattle, Washington | FORMOSA MINE<br>PRELIMINARY ASSESSMENT<br>Douglas County, Oregon | Figure 3<br>MIDDLE CREEK M3.1 TO MIDDLE CREEK M7.9 | |
| | 0 2000 4000<br>Approximate Scale in Feet | Date: 1-23-07 / Drawn by: AES | 10:START-3\06010033\fig 3 |

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|---|---|---|---|---|
| **ecology and environment, inc.**<br>International Specialists in the Environment<br>Seattle, Washington | FORMOSA MINE<br>PRELIMINARY ASSESSMENT<br>Douglas County, Oregon | Figure 4<br>MIDDLE CREEK M9.8 TO<br>EXTENT OF TARGET DISTANCE LIMIT | | |
| | 0 2000 4000<br>Approximate Scale in Feet | Date:<br>1-24-07 | Drawn by:<br>AES | 10:START-3\06010033\fig 4 |

## SOURCE DESCRIPTION

### 2.2 SOURCE CHARACTERIZATION

Number of the Source: 1

Name and description of the source: Waste Rock Piles (Pile)
Source 1 consists of two waste rock piles which are present at the Formosa Mine site. One waste rock pile is associated with the Formosa 1 Adit and the other is associated with the Silver Butte Adit. The Formosa 1 Adit and the Silver Butte Adit both access the same ore body (Ref. 8, p. 9). The ore bodies accessed by these adits are massive sulfide, volcanic-exhalitive type deposits rich in copper and zinc (Ref. 8, p. 9). Waste rock, during the early periods of mine operation (i.e., the early 1900s to 1933), was dumped on the hillsides below the adits (Ref. 6, p. 2).

EPA has not conducted a site inspection (SI) at the Formosa Mine; however, two privately funded investigations have been conducted which included sampling of these waste rock piles. The privately funded investigations were the Environmental Site Assessment conducted by Dynamac Corporation in 2000 (Ref. 6) and the Supplemental Remedial Investigation conducted by Hart Crowser, Inc in 2004 (Ref. 4). Data from these investigations will be used to document the presence of hazardous substances in the waste rock piles.

**Final Site Assessment (Ref. 6):** In October 1999, fieldwork for a site assessment was conducted (Ref. 6, p. ES-1). During this field work, two waste rock samples (SB-WS-1 and SB-WS-2) were collected from the Formosa Adit and Silver Butte Adit waste rock piles (Ref. 6, p. 12). A workplan was developed for this field work (Ref. 10). Sample SB-WS-1 was collected from the Formosa 1 Adit waste rock pile and sample SB-WS-2 was collected from the Silver Butte Adit waste rock pile (Ref. 6, p. 12). The samples were sent under chain-of-custody to a fixed laboratory for analysis of TAL metals using method 6010B (Ref. 6, p. 160). Hazardous substances detected at significant concentrations in waste rock samples include arsenic, barium, copper, lead, mercury, and zinc (see Table 1 below).

**Supplemental Remedial Investigation (Ref. 4):** A Supplemental Remedial Investigation was conducted from November 2001 through May 2002 (Ref. 4, p. 6). Waste rock leach cells were constructed in the field to contain waste rock that was exposed to rainfall and then sampled (Ref, 4, p. 16; Ref. 7, p. 38). Two to three cubic yards of waste rock was collected using an excavator and placed into a leaching cell (Ref. 4, p. 16). The excavation of the waste rock was a maximum of 4 feet below ground surface (bgs) (Ref. 4, p. 77). In December 2001, two five-point composite waste rock samples (Cell 2 and Cell 3) were collected (Ref. 4, pp. 16 and 50). The five-point composite waste rock samples were collected from waste rock in the leaching cells using a stainless steel spoon and mixed in a stainless steel bowl (Ref. 4, p. 77). The cell 2 sample was collected from the waste rock pile associated with the Silver Butte Adit and the cell 3 sample was collected from the waste rock pile associated with the Formosa 1 Adit (Ref. 4, p. 50). The samples were placed in samples jars then in a cooler for delivery to a fixed laboratory for analyses (Ref. 4, p. 77). The samples were sent under chain-of-custody for analysis of total metals using methods 6010 and 6020 (Ref. 4, p. 529). Hazardous substances detected at significant concentrations in waste rock samples include arsenic, copper, and lead (see Table 2 below). Following the waste rock sampling, the cells were exposed to rainwater and then leachate samples were collected (Ref. 4, p. 16). These leachate samples are separate from the

samples discussed above (Ref. 4, p. 16), and have not been used to document hazardous substances associated with source 1.

Location of the source, with reference to a map:
The two piles are located at the Formosa 1 Adit and the Silver Butte Adit (Ref. 6, pp. 5).

Containment
Release to Surface Water via Overland Migration and/or Flood: The source consists of two distinct waste rock piles. Photographs of the waste rock pile at the Silver Butte Adit indicate that no cover is present over the pile and that the surface of the pile is exposed (Ref. 6, p. 65; Ref. 9, p. 87). These waste rock piles are located on overly steep slopes, not contained, and easily transported by gravity or surface water runoff (Ref. 6, p. 14). A surface water containment factor value of 10 is assigned because available documentation does not indicate the presence of a maintained engineered cover, or functioning and maintained run-on control system and runoff management system at the waste rock piles (Ref. 1, p. 51609, Table 4-2).

Containment Value: 10

### 2.2.2 Hazardous Substances

Tables 1 and 2 below provide hazardous substances associated with Source 1 based on the two earlier field sampling events discussed in Section 2.2.

Table 1 below lists hazardous substances present in the waste rock piles at observed release concentrations based on analytical results from the Final Environmental Site Assessment (Ref. 6). Although not required when determining the hazardous substances associated with a pile, only waste rock sample results meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 1 below. For this table, sample SB-S-BG, collected approximately 0.49 mile north of the Formosa Mine along BLM road 31-6-13.1, is used as the background sample (Ref 6, p. 29). This sample was collected upgradient and outside the range of mining activities that occurred at the Formosa Mine (Ref. 6, pp. 20 and 21).

**Table 1 Hazardous Substances Associated with Source 1 from the Environmental Site Assessment (units = mg/kg)**

| Sample Number | SB-S-BG | SB-WS-1 | SB-WS-2 |
|---|---|---|---|
| **Location** | **Background** | **Formosa 1 Adit Waste Rock Pile** | **Silver Butte Adit Waste Rock Pile** |
| **Reference** | **Ref. 6, pp. 102, 161, 164 through 167; Ref. 40, p. 9** | **Ref. 6, pp. 75, 160, 164 through 167; Ref. 40, p. 4** | **Ref. 6, pp. 78, 160, 164 through 167; Ref. 40, p. 5** |
| | | | |
| **Analyte** | | | |
| Arsenic | <50 (MRL = 50) | | 170 (MRL = 5.0) |
| Barium | 150 (MRL = 50) | 1700 (MRL = 5.0) | 700 (MRL = 5.0) |
| Copper | 67 (MRL = 50) | 440 (MRL = 5.0) | 530 (MRL = 5.0) |
| Lead | <50 (MRL = 50) | | 330 (MRL = 5.0) |
| Mercury | <0.10 (MRL = 0.10) | 0.68 (MRL = 0.10) | 3.4 (MRL = 1.0) |
| Zinc | 140 (MRL = 100) | 700 (MRL = 10) | |

Note: Blank cells indicate that the associated result did not meet observed release criteria.

Key:

mg/kg = milligrams per kilogram.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

Table 2 below lists hazardous substances present in the waste rock piles at observed release concentrations based on analytical results from the Supplemental Remedial Investigation (Ref. 4). Although not required when determining the hazardous substances associated with a pile, only waste rock sample results meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 2 below. For this table, sample SB-S-BG, collected approximately 0.49 mile north of the Formosa Mine along BLM road 31-6-13.1, is used as the background sample (Ref 6, p. 29). This sample was collected upgradient and outside the range of mining activities that occurred at the Formosa Mine (Ref. 6, pp. 20 and 21).

**Table 2 Hazardous Substances Associated with Source 1 from the Supplemental Remedial Investigation (units = mg/kg)**

| **Sample Number** | **SB-S-BG** | **Cell 2** | **Cell 3** |
|---|---|---|---|
| **Location** | **Background** | **Silver Butte Adit Waste Rock** | **Formosa 1 Adit Waste Rock** |
| **Reference** | **Ref. 6, pp. 102, 161, 164 through 167; Ref. 40, p. 9** | **Ref. 4, pp. 518, 529; Ref. 41, p. 26** | **Ref. 4, pp. 520, 529; Ref. 41, p. 27** |
| **Analyte** | | | |
| Arsenic | <50 (MRL = 50) | 264 JL (MRL = 5.00) | 68.8 JL (MRL = 1.00) |
| Copper | 67 (MRL = 50) | 404 (MRL = 1.00) | 326 (MRL = 1.00) |
| Lead | <50 (MRL = 50) | 657 JK (AC = 456.25) (MRL = 1.00) | 184 JK (AC = 127.78) (MRL = 1.00) |

Key:

AC = Adjusted concentration (Ref. 42, pp. 8, 18).
mg/kg = milligrams per kilogram.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.
J = Value is estimated, however, the identification is not in doubt.
K = Unknown bias.
L = Low bias.

SD – Hazardous Waste Quantity

Source No.: 1

**2.4.2 Hazardous Waste Quantity**

**2.4.2.1.1 Hazardous Constituent Quantity**

Available data are insufficient to document a hazardous constituent quantity (Ref. 1, p. 51590, Section 2.4.2.1.1).

Hazardous Constituent Quantity Value (C): NS

**2.4.2.1.2 Hazardous Wastestream Quantity**

Available data are insufficient to document a hazardous wastestream quantity (Ref. 1, p. 51591, Section 2.4.2.1.2).

Hazardous Wastestream Quantity (W): NS

**2.4.2.1.3 Volume**

The Formosa 1 Adit waste rock pile is estimated to be 1,900 cubic yards and the Silver Butte Adit waste rock pile is estimated to be 5,700 cubic yards (Ref. 6, pp. 12 and 14). The total volume of waste rock associated with source 1 is estimated to be 7,600 cubic yards (i.e., 1,900 cubic yards + 5,700 cubic yards = 7,600 cubic yards).

The value assigned to the volume measure is calculated as follows:

7,600 cubic yards/2.5 for source type pile (Ref. 1, p. 51591)= 3,040

Volume Assigned Value (V): 3,040
Ref. 1, p. 51591 Table 2-5

**2.4.2.1.4 Area**

Since the volume measure was determined, the area measure was not evaluated (Ref. 1, p 51591, Section 2.4.2.1.4).

Area Assigned Value (A): 0

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Source Hazardous Waste Quantity Value: 3,040

## SOURCE DESCRIPTION

### 2.2 SOURCE CHARACTERIZATION

Number of the Source: 2

Name and description of the source: Waste Rock Pile (Pile)
Source 2 consists of one waste rock pile which is present at the Formosa Mine site. This waste rock pile is associated with the 404 Adit (Ref. 4, p. 21). Waste rock, during the early periods of mine operation (i.e., the early 1900s to 1933), was dumped on the hillsides below the adits (Ref. 6, p. 2).

EPA has not conducted an SI at the Formosa Mine; however, one privately funded investigation was conducted that included sampling of the waste rock pile at the 404 Adit. This privately funded investigation was the Environmental Site Assessment conducted by Dynamac Corporation in 2000 (Ref. 6). Data from this investigation will be used to document the presence of hazardous substances in the waste rock pile at the 404 adit.

**Final Environmental Site Assessment (Ref. 6):** In October 1999, fieldwork for a site assessment was conducted (Ref. 6, p. ES-1). During this field work, one waste rock sample, SB-WS-404, was collected from the 404 adit waste rock pile (Ref. 6, p. 12). A workplan was developed for this work (Ref. 10). The sample was sent under chain-of-custody to a fixed laboratory for analysis of TAL metals using method 6010B (Ref. 6, p. 160). Hazardous substances detected at significant concentrations in the waste rock sample include lead and mercury (see Table 3 below).

Location of the source, with reference to a map:
The waste rock pile is located at the 404 Adit (Ref. 6, p. 5).

Containment
Release to Surface Water via Overland Migration and/or Flood: The source consists of a single waste rock pile. A photograph of the waste rock pile at the 404 Adit indicates that no cover is present over the pile and that the surface of the pile is exposed (Ref. 6, p. 67). This waste rock pile is located on an overly steep slope, not contained, and easily transported by gravity or surface water runoff (Ref. 6, p. 14). A surface water containment factor value of 10 is assigned because available documentation does not indicate the presence of a maintained engineered cover, or functioning and maintained run-on control system and runoff management system at the waste rock pile (Ref. 1, p. 51609, Table 4-2).

Containment Value: 10

### 2.2.2 Hazardous Substances

Table 3 below lists hazardous substances present in the 404 Adit waste rock pile at observed release concentrations based on analytical results from the Final Site Assessment (Ref. 6). Although not required when determining the hazardous substances associated with a pile, only waste rock sample results meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 3 below. For this table, sample SB-S-BG, collected approximately 0.49 mile north of the Formosa Mine along BLM road 31-6-13.1, is used as the background sample (Ref 6, p. 29). This sample was collected upgradient and outside the range of mining activities that occurred at the Formosa Mine (Ref. 6, pp. 20 and 21).

**Table 3 Hazardous Substances Associated with Source 2 from the Environmental Site Assessment (units = mg/kg)**

| **Sample Number** | **SB-S-BG** | **SB-WS-404** |
|---|---|---|
| **Location** | **Background** | **404 Adit Waste Rock Pile** |
| **Reference** | **Ref. 6, 102, 161, 164 through 167; Ref. 40, p. 9** | **Ref. 6, pp. 87, 160, 164 through 167; Ref. 40, p. 7** |
| Lead | <50 (MRL = 50) | 160 (MRL = 5.0) |
| Mercury | <0.10 (MRL = 0.10) | 0.89 (MRL = 0.10) |

Key:

mg/kg = milligrams per kilogram.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

### 2.4.2 Hazardous Waste Quantity

#### 2.4.2.1.1 Hazardous Constituent Quantity

Available data are insufficient to document a hazardous constituent quantity (Ref. 1, p. 51590, Section 2.4.2.1.1).

Hazardous Constituent Quantity Value (C): NS

#### 2.4.2.1.2 Hazardous Wastestream Quantity

Available data are insufficient to document a hazardous wastestream quantity (Ref. 1, p. 51591, Section 2.4.2.1.2).

Hazardous Wastestream Quantity (W): NS

#### 2.4.2.1.3 Volume

The 404 Adit waste rock pile is estimated to be 20 cubic yards (Ref. 6, pp. 12 and 14). The value assigned to the volume measure is calculated as follows:

20 cubic yards/2.5 for source type piles (Ref. 1, p. 51591) = 8

Volume Assigned Value (V): 8
Ref. 1, p. 51591 Table 2-5

#### 2.4.2.1.4 Area

Since the volume measure was determined, the area measure was not evaluated (Ref. 1, p 51591, Section 2.4.2.1.4).

Area Assigned Value (A): 0

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Source Hazardous Waste Quantity Value: 8

## SOURCE DESCRIPTION

### 2.2 SOURCE CHARACTERIZATION

Number of the source: 3

Name and description of the source: Encapsulation Mound (Surface Impoundment – Buried/Backfilled)

Source 3 consists of an encapsulation mound at the Formosa Mine, which is the former tailings pond for the mill (Ref. 8, pp. 14 and 15). A mill was constructed at the south of the Formosa 1 Adit (Ref. 8, p. 14). The milling process was planned to consist of a grinding circuit to reduce the ore to 200-mesh followed by froth flotation to produce both copper and zinc concentrates, which would then be sent off-site for smelting and refining (Ref. 17, p. 3). Mill tailings were then to be filter pressed to get them into a solid state and then were to be temporarily stored in part of the tailings area (encapsulation mound) (Ref. 17, p. 3). Actual milling processes could not be verified from the available documentation.

A pond covering approximately two acres was constructed south of the mill area (Ref. 8, pp. 10, 15). The pond was lined with two layers of PVC with a leak detection system between the two layers and designed mainly as a water storage facility with the capacity to temporarily store tails (Ref. 8, p. 15). The planned milling process was intended to use approximately 1,100 gallons of water per day (Ref. 17, p. 3). All of the runoff water that came into contact with ore or tailings, plus runoff water from some other areas of the mill facility, was to be directed into the pond, which would then be mixed with various chemicals for use in the flotation process (Ref. 17, p. 3). Although the actual processes used could not be verified from available information, the pond was gradually filled with excess tailings (Ref. 8, p. 15). By the summer of 1993, Formosa Exploration had filled the pond with tailings to and above the maximum permitted level and had started filtering the tailings and dry stacking them on an extension of liner south of the pond (Ref. 8, p. 15). This material was then gradually pushed north over the wet tailings (Ref. 8, p. 15). The upper liner of the pond was punctured some time during Formosa Exploration's operations and the bottom liner remained intact, but was ripped during removal of the dry stacked tailings (Ref. 8, p. 15). Pumping of the pond began in September and was completed in May, then the pond was backfilled with low grade ore in May and June (Ref. 8, p. 15). Based on the date of this reference (i.e., Reference 8), it appears this work began in 1993 and ended in 1994 (Ref. 8, pp. 1 and 15). A Bentomat cover (a woven fabric with natural bentonite embedded in it at a uniform thickness) was placed over the backfilled pond and a minimum of 4.2 feet of soil cap was placed on the cover with an average thickness of 7.25 feet (Ref. 8, p. 16). This cover is also a combination of sulfide-rich soil mixed with limestone and treated oil-contaminated soil (Ref. 6, p. 8). Acidic water flows from the encapsulation mound (Ref. 6, p. 7).

The EPA has not conducted an SI at the Formosa Mine; however, two privately funded investigations have been conducted and an EPA-funded Removal Assessment is currently being conducted. The privately funded investigations were the Final Site Assessment conducted by Dynamac Corporation in 2000 (Ref. 6) and the Supplemental Remedial Investigation conducted by Hart Crowser, Inc in 2004 (Ref. 4). The EPA Removal Assessment is being conducted by Ecology & Environment Inc. Data from these investigations will be used to document the presence of hazardous substance in the encapsulation mound.

**Final Site Assessment (Ref. 6):** In October 1999, fieldwork for an environmental site assessment was conducted (Ref. 6, p. ES-1). During this field work, three samples from the encapsulation mound (SB-WS-3, SB-WS-4, and SB-S-4) were collected (Ref. 6, pp. 12 and 20). A workplan was developed for this field work (Ref. 10). Sample SB-WS-3 was collected from the top of the encapsulation mound, approximately 50 feet north of the south edge and sample SB-WS-4 was collected from the southeastern corner of the encapsulation mound (Ref. 6, p. 12). Sample SB-S-4 was collected at the base of the encapsulation mound approximately 85 feet from the south edge (Ref. 6, p. 20). The samples were sent under chain-of-custody to a fixed laboratory for analysis of TAL metals using method 6010B (Ref. 6, pp. 160 and 161). Hazardous substances detected at significant concentrations in encapsulation mound samples include arsenic, barium, copper, lead, mercury, and zinc (see Table 4 below).

**Supplemental Remedial Investigation (Ref. 4):** Data collection for a Supplemental Remedial Investigation was conducted from November 2001 through May 2002 (Ref. 4, p. 6). In December 2001, two encapsulation mound test pits (S-1 and S-2) were excavated (Ref. 4, pp. 15, 49, and 59). A total of two samples (S-1 and S-2) were collected from the test pits (Ref. 4, p. 49). The test pits were completed to collect soil samples and verify the presence of a low permeability cap which available evidence suggested was more than 20 feet bgs (Ref. 4, p. 15; Ref. 7, p. 11). At each location, sandbags on the existing plastic cover were removed, the cover pulled back, and an excavator was used to excavate the test pit until the cap was encountered or until equipment limitations prevented deeper excavation (Ref. 4, p. 15). Sample S-1 was collected from 2 feet bgs and sample S-2 was collected from 3 feet bgs (Ref. 4, p. 49). The samples were placed in sample jars then in a cooler for delivery to a fixed laboratory for analyses (Ref. 4, p. 77). The samples were sent under chain-of-custody for analysis of total metals using methods 6010 and 6020 (Ref. 4, p. 529). Hazardous substances detected at significant concentrations in encapsulation mound samples include lead (see Table 5 below).

**Removal Assessment (Ref. 14):** Fieldwork for a Removal Assessment was conducted from June 26 to 29, 2006 and from July 5 to 7, 2006 (Ref. 14, p. 1). During the assessment, five borehole locations (EM01 though EM05) were completed in the encapsulation mound (Ref. 14, pp. 1 and 3). All samples collected from the boreholes were field screened using an Innov-X Systems X-Ray Fluorescence Analyzer (Ref. 14, p. 1). Selected samples collected from these boreholes were submitted for fixed laboratory analysis (Ref. 14, p. 70). Borehole EM01 was drilled to a depth of 3 feet bgs, where refusal was encountered (Ref. 14, p. 30). The remaining boreholes (EM02, EM03, EM04, and EM05) were drilled to a depth of 8 feet bgs (Ref. 14, pp. 31 through 34). Sample 06-06-0014 was collected from borehole EM03 from 0 to 4 feet bgs and sample 06-06-0019 was collected from borehole EM05 from 4 to 8 feet bgs (Ref. 14, pp. 2A, 70). The samples were collected by cutting open the dedicated Teflon liner, logging the lithology of the core, then removing the sample material with a dedicated stainless steel spoon and placing it into a dedicated stainless steel bowl; the samples were then thoroughly homogenized and placed into prelabeled containers (Ref. 14, pp. 1). The samples were placed on ice in a cooler and maintained under chain-of-custody (Ref. 14, pp. 2, 72). The samples were analyzed for total TAL metals by EPA Method SW-6010B (Ref. 14, pp. 2, 76). Hazardous substances detected at significant concentrations in encapsulation mound samples include arsenic, cadmium, copper, lead, mercury, and zinc (see Table 6 below).

Location of the source, with reference to a map:
The encapsulation mound is located between the 404 Adit and the Silver Butte Adit and immediately adjacent to the former mill site (Ref. 4, p. 56).

Containment:
Release to Surface Water via Overland Migration and/or Flood: The source consists of an encapsulation mound. Acidic water flows from the encapsulation mound (Ref. 6, p. 7). A surface water containment factor value of 10 is assigned because there is no evidence that the encapsulation mound's cover is maintained and there is no evidence that there is a functioning and maintained run-on control system and runoff management system (Ref. 8, p. 15; Ref. 1, p. 51610, Table 4-2).

Containment Value: 10

### 2.2.2 Hazardous Substances

Tables 4, 5, and 6 below provide hazardous substances associated with Source 3 based on the three earlier field sampling events discussed in Section 2.2.

Table 4 below lists hazardous substances present in the encapsulation mound at observed release concentrations based on analytical results from the Final Environmental Site Assessment (Ref. 6). Although not required when determining the hazardous substances associated with a pile, only encapsulation mound sample results meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 4 below. For this table, sample SB-S-BG, collected approximately 0.49 mile north of the Formosa Mine along BLM road 31-6-13.1, is used as the background sample (Ref 6, p. 29). This sample was collected upgradient and outside the range of mining activities that occurred at the Formosa Mine (Ref. 6, pp. 20 and 21).

**Table 4 Hazardous Substances Associated with Source 3 from the Environmental Site Assessment (units = mg/kg)**

| Sample Number | SB-S-BG | SB-WS-3 | SB-WS-4 | SB-S-4 |
|---|---|---|---|---|
| Location | Background | Encapsulation Mound | | |
| Reference | Ref. 6, pp. 102, 161, 164 through 167; Ref. 40, p. 9 | Ref. 6, pp. 81, 160, 164 through 167; Ref. 40, p. 6 | 84, 160, 164 through 167; Ref. 40, p. 26 | 99, 161, 164 through 167; Ref. 40, p. 8 |
| **Analyte** | | | | |
| Arsenic | <50 (MRL = 50) | 66 (MRL = 5.0) | | |
| Barium | 150 (MRL = 50) | | 680 (MRL = 5.0) | 1300 (MRL = 5.0) |
| Copper | 67 (MRL = 50) | 1,000 (MRL = 5.0) | 240 (MRL = 5.0) | |
| Lead | <50 (MRL = 50) | | | |
| Mercury | <0.10 (MRL = 0.10) | 0.37 (MRL = 0.10) | 0.18 (MRL = 0.10) | 0.48 (MRL = 0.10) |
| Zinc | 140 (MRL = 100) | 2,000 (MRL = 200) | | 590 (MRL = 10) |

Note: Blank cells indicate that the associated result did not meet observed release criteria.

Key:

mg/kg = milligrams per kilogram.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

Table 5 below lists hazardous substances present in the encapsulation mound at observed release concentrations based on analytical results from the Supplemental Remedial Investigation (Ref. 4). Although not required when determining the hazardous substances associated with a pile, only encapsulation mound sample results meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 5 below. For this table, sample SB-S-BG, collected approximately 0.49 mile north of the Formosa Mine along BLM road 31-6-13.1, is used as the background sample (Ref 6, p. 29). This sample was collected upgradient and outside the range of mining activities that occurred at the Formosa Mine (Ref. 6, pp. 20 and 21).

| **Table 5** | **Hazardous Substances Associated with Source 3 from the Supplemental Remedial Investigation (units = mg/kg)** | |
|---|---|---|
| **Sample Number** | **SB-S-BG** | **S-1** |
| **Location** | **Background** | **Encapsulation Mound** |
| **Reference** | **Ref. 6, pp. 102, 161, 164 through 167; Ref. 40, p. 9** | **Ref. 4, pp. 512 and 529; Ref. 41, p. 25** |
| **Analyte** | | |
| Lead | <50 (MRL = 50) | 51.6 (MRL = 1.00) |

Key:

mg/kg = milligrams per kilogram.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

Table 6 below lists hazardous substances present in the encapsulation mound at observed release concentrations based on analytical results from the Removal Assessment (Ref. 14). Although not required when determining the hazardous substances associated with a pile, only encapsulation mound sample results meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 6 below. For this table, sample SB-S-BG, collected approximately 0.49 mile north of the Formosa Mine along BLM road 31-6-13.1, is used as the background sample (Ref 6, p. 29). This sample was collected upgradient and outside the range of mining activities that occurred at the Formosa Mine (Ref. 6, pp. 20 and 21).

| **Table 6** | **Hazardous Substances Associated with Source 3 from the Removal Assessment (units = mg/kg)** | | |
|---|---|---|---|
| **Sample Number** | **SB-S-BG** | **06-06-0014** | **06-06-0019** |
| **Location** | **Background** | **Location EM03 in Encapsulation Mound** | **Location EM05 in Encapsulation Mound** |
| **Reference** | **Ref. 6, pp. 102, 161, 164 through 167; Ref. 40, p. 9** | **Ref. 14, pp. 56 through 72, 78, 79, 80, and 83** | **Ref. 14, pp. 56 through 72, 78, 79, 80, and 84** |
| **Analyte** | | | |
| Arsenic | <50 (MRL = 50) | 82.4 (MRL = 0.5) | 179 (MRL = 0.6) |
| Cadmium | <20 (MRL = 20) | | 26.3 (MRL = 1.1) |
| Copper | 67 (MRL = 50) | 1,100 (MRL = 2.2) | 4,420 (MRL = 2.2) |
| Lead | <50 (MRL = 50) | 91.8 (MRL = 22) | 90.6 (MRL = 22) |
| Mercury | <0.10 (MRL = 0.10) | 0.67 (MRL = 0.02) | 2.26 (MRL = 0.10) |
| Zinc | 140 (MRL = 100) | | 4,380 (MRL = 2.2) |

Note: Blank cells indicate that the associated result did not meet observed release criteria.

Key:

mg/kg = milligrams per kilogram.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

### 2.4.2 Hazardous Waste Quantity

#### 2.4.2.1.1 Hazardous Constituent Quantity

Available data are insufficient to document a hazardous constituent quantity (Ref. 1, p. 51590, Section 2.4.2.1.1).

Hazardous Constituent Quantity (C): NS

#### 2.4.2.1.2 Hazardous Wastestream Quantity

Available data are insufficient to document a hazardous wastestream quantity (Ref. 1, p. 51591, Section 2.4.2.1.2).

Hazardous Wastestream Quantity (W): NS

#### 2.4.2.1.3 Volume

The volume of the encapsulation mound is estimated to be 26,515 cubic yards (Ref. 14, p. 1). The value assigned to the volume measure is calculated as follows:

26,515 cubic yards/2.5 for source type surface impoundment (buried/backfilled) (Ref. 1, p. 51591) = 10,606

Volume Assigned Value: 10,606
Ref. 1, p. 51591, Table 2-5

#### 2.4.2.1.4 Area

Since the volume measure was determined, the area measure was not evaluated (Ref. 1, p 51591, Section 2.4.2.1.4).

Area Assigned Value (A): 0

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Source Hazardous Waste Quantity Value: 10,606

## SOURCE DESCRIPTION

### 2.2 SOURCE CHARACTERIZATION

Number of Source: 4

Name and Description of the Source: Formosa 1 and Silver Butte Adit discharges (other)

Source 4 consists of water discharging from two related mine adits at the Formosa Mine. These are the Formosa 1 Adit and the Silver Butte Adit (Ref. 6. p. 4). The Formosa 1 Adit and the Silver Butte Adit both access the same ore body (Ref. 8, p. 9). The ore bodies accessed by these adits are massive sulfide, volcanic-exhalitive type deposits rich in copper and zinc (Ref. 8, p. 9). After mining operations ceased in 1993, Formosa Exploration, Inc., backfilled the adits with the most reactive material found at the Formosa Mine which included mill tailings and high-grade-crushed ore (Ref. 6, p. 8). Additionally, 750 tons of crushed ore which had been stockpiled north of the former mill was used to backfill the adits (Ref. 8, p. 14). In total, approximately 53,400 cubic yards of material were backfilled into the mine workings (Ref. 21, pp. 29, 350 through 361). The adits were then capped with concrete and limestone rock, and drainage pipe and water dispersal fields were installed (Ref. 6, p. 8). In 1994, drain fields were constructed to direct acid mine drainage from the Formosa 1 Adit and Silver Butte Adit away from Middle Creek (Ref. 9, p. 5). During the wet weather, water has been observed to flow directly out of both adits, bypassing the drainage pipes (Ref. 30, p. 3). Precipitation of iron minerals plugged these drains in late 1995/early 1996; the drain line was replaced, but again failed in late 1997 and in April 2000 (Ref. 6, p. 8; Ref. 9, pp. 5, 88). In 1996, water from the Formosa 1 Adit, was flowing down the roadside ditch, through a culvert under the road, and directly into Middle Creek (Ref. 6, p. 8; Ref. 30, p. 3).

Flow rates for the Formosa 1 and Silver Butte adits have been collected from June 1999 through May 2002 (Ref. 4, p. 29; Ref. 6, p. 29; Ref. 9, p. 92). Flow rates for the Formosa 1 Adit ranged from 0.0029 cubic feet per second (cfs) to 0.4240 cfs (Ref. 4, p. 29, Ref. 9, p. 92). Flow rates for the Silver Butte Adit ranged from 0 cfs to 0.0439 cfs (Ref. 4, p. 29, Ref. 9, p. 92). The flow rate as measured in 1999 during the Site Assessment indicates a flow at Formosa 1 Adit as 1 gallon per minute (gpm) (Ref. 6, p. 29).

The EPA has not conducted an SI at the Formosa Mine; however, three privately funded investigations have been conducted, the Environmental Site Assessment conducted by Dynamac Corporation in 2000 (Ref. 6), the Remedial Investigation conducted by Oregon Department of Environmental Quality and the Bureau of Land Management in 2000 (Ref. 5), and the Supplemental Remedial Investigation conducted by Hart Crowser, Inc in 2002 (Ref. 4). Data from these investigations will be used to document the presence of hazardous substance in the adit discharges.

**Final Site Assessment (Ref. 6):** In October 1999, fieldwork for an environmental site assessment was conducted (Ref. 6, p. ES-1). During this field work, a surface water sample, SB-SW-1, was collected from the Formosa 1 Adit (Ref. 6, pp. 27 and 28). This sample was collected directly from the adit discharge (Ref. 6, p. 27). A workplan was developed for this fieldwork (Ref. 10). The sample was sent under chain-of-custody to a fixed laboratory for analysis of TAL metals using EPA Method 6010B (Ref. 6, pp. 160; Ref. 10, p. 26). Hazardous

substances detected at significant concentrations in the adit water include beryllium, cadmium, cobalt, copper, manganese, nickel, and zinc (see Table 7 below)

**Remedial Investigation (Ref. 5):** A remedial investigation was conducted from 1999 to 2000 (Ref. 5, p. 7). Surface water samples were collected from the Formosa 1 Adit on October 5, 1999, January 26, 2000, February 14, 2000, and March 23, 2000 (Ref. 5, pp. 5 and 11; Ref. 16, pp. 1, 54, 110, and 133). Surface water samples were collected from the Silver Butte Adit on January 26, 2000, February 14, 2000, and March 23, 2000 (Ref. 5, pp. 5 and 11; Ref. 16, pp. 1, 54, and 133). The surface water samples were collected by placing the open bottle upstream and allowing it to fill (Ref. 5, p. 10; Ref. 23, p. 82). Since method reporting limits are only provided for the sample results collected on March 23, 2000, only data from this date will be used to determine hazardous substances associated with these adits. The samples were sent under chain-of-custody to a fixed laboratory for analysis of dissolved metals using EPA 200 Series method (Ref. 16, pp. 1, 54, 110, 133). Hazardous substances detected in adit water samples include antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, and zinc (see Table 8 below).

**Supplemental Remedial Investigation (Ref. 4):** Data collection for a Supplemental Remedial Investigation was conducted from November 2001 through May 2002 (Ref. 4, p. 6). Surface water samples were collected from the Formosa 1 Adit on November 8 and 30, 2001; December 18, 2001; February 7 and 21, 2002; March 26, 2002; April 22, 2002; and May 29, 2002 (Ref. 4, p. 29). Various sample identifiers were used on the analytical data forms and include Formosa Adit, Formosa-F-audit (sic), F & S adits, combined adit floor, combined adits, and F-adit (Ref. 4, pp. 29, 251, 283, 303, 307, 331, 353, 373, 405, 457). Surface water samples were collected from the Silver Butte Adit (referred to as the "Silver Butter Adit" on the analytical data sheet) on December 18, 2001 (Ref. 4, pp. 29 and 303). The surface water samples were collected by dipping a collection bottle into the water and using a peristaltic pump to transfer the water through a 0.045 micron filter into the laboratory supplied bottle; the samples were then placed in a cooler with ice (Ref. 4, p. 72). The samples were sent under chain-of-custody to a fixed laboratory for analysis of dissolved metals using EPA Method 6010B (Ref. 4, pp. 281, 301, 323, 349, 370, 373, 403, 434, and 474). Hazardous substances detected in adit water samples include arsenic, cadmium, copper, lead, manganese, nickel, and zinc (see Table 9 below).

Location of the source, with reference to a map:
The Formosa 1 Adit is located near the headwaters of Middle Creek and the Silver Butte Adit is located northeast of the encapsulation mound (Ref. 6, p. 28).

Containment:
Release to Surface Water via Overland Migration and/or Flood: Formosa 1 Adit water has flowed directly into Middle Creek (Ref. 30, p. 3). Adit water from the Formosa 1 Adit and the Silver Butte Adit flowed into one of the upper branches of Middle Creek (Ref. 35, pp. 2, 3, and 8). A surface water containment factor value of 10 is assigned based on evidence of hazardous substance migration from the source area (Ref. 1, p. 51609, Table 4-2).

Containment Value: 10

### 2.2.2 Hazardous Substances

Samples of the backfilled material are not known to have been collected; however, water emerging from two Formosa Mine adits has been sampled. Tables 7, 8, and 9 below provide hazardous substances associated with Source 4 based on the three earlier field sampling events discussed in Section 2.2.

Although not required when determining the hazardous substances associated with a waste source, only adit water sample results from the Environmental Site Assessment meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 7 below. Sample SB-SW-SFU will be used as the background sample for sample SB-SW-1 for this purpose. This sample was collected from the headwaters of South Fork Middle (Ref. 6, p. 28).

**Table 7 Hazardous Substances Associated with Source 4 from the Environmental Site Assessment (units = mg/L)**

| **Sample Number** | **SB-SW-SFU** | **SB-SW-1** |
|---|---|---|
| **Location** | **Background** | **Formosa 1 Adit** |
| **Reference** | **Ref. 6, pp. 121, 159, 164 through 167; Ref. 40, pp. 21, 22** | **Ref. 6, pp. 109, 160, 164 through 167; Ref. 40, p. 10** |
| Beryllium | <0.0010 (MRL = 0.0010 | 0.0013 (MRL = 0.0010) |
| Cadmium | <0.0010 (MRL = 0.0010) | 0.41 (MRL = 0.0010) |
| Cobalt | <0.010 (MRL = 0.010) | 0.042 (MRL = 0.010) |
| Copper | <0.010 (MRL = 0.010) | 14 (MRL = 0.010) |
| Manganese | <0.010 (MRL = 0.010) | 3.5 (MRL = 0.010) |
| Nickel | <0.010 (MRL = 0.010) | 0.14 (MRL = 0.010) |
| Zinc | <0.050 (MRL = 0.050) | 140 (MRL = 1.00) |

Key:

mg/L = milligrams per liter.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

Table 8 below provides hazardous substances associated with Source 4 based on sample results from the Remedial Investigation (Ref. 5; Ref. 16).

| **Table 8 Hazardous Substances Associated with Source 4 from the Remedial Investigation (units = mg/L)** | | |
|---|---|---|
| **Sample Name** | **Formosa 1 Adit** | **Silver Butte Adit** |
| **Page No. in Reference 16** | **1, 5, 6, 16, and 17** | **1, 5, 6, and 16** |
| **Analyte** | | |
| Antimony | 0.00163 (MRL = 0.00100) | ND |
| Arsenic | 0.156 (MRL = 0.00765) | 0.00242 (MRL = 0.00100) |
| Barium | 0.0135 (MRL = 0.00200) | 0.0200 (MRL = 0.00200) |
| Cadmium | 0.728 (MRL = 0.00765) | 0.275 (MRL = 0.00776) |
| Chromium | 0.0171 (MRL = 0.00100) | 0.00362 (MRL = 0.00100) |
| Cobalt | 0.0325 (MRL = 0.00200) | 0.0161 (MRL = 0.00200) |
| Copper | 38.3 (MRL = 0.500) | 18.2 (MRL = 0.200) |
| Lead | 0.0351 (MRL = 0.00100) | 0.0774 (MRL = 0.00100) |
| Manganese | 2.57 (MRL = 0.0100) | 1.65 (MRL = 0.0100) |
| Nickel | 0.130 (MRL = 0.00200) | 0.0500 (MRL = 0.00200) |
| Selenium | 0.0143 (MRL = 0.00100) | 0.00532 (MRL = 0.00100) |
| Zinc | 182 (MRL = 1.25) | 49.3 (MRL = 0.500) |

Key:

ND = Not detected.
No. = Number.
mg/L = milligrams per Liter.
MRL = Method reporting limit.

Table 9 below provides hazardous substances associated with Source 4 based on sample results from the Supplemental Remedial Investigation (Ref. 6).

| Table 9 Hazardous Substances Associated with Source 4 from the Supplemental Remedial Investigation (units = mg/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sample Location** | **Formosa 1 Adit** | | | | | | | | **Silver Butte Adit** |
| **Sample Date** | **11/8/01** | **11/30/01** | **12/18/01** | **2/7/02** | **2/21/02** | **3/26/02** | **4/22/02** | **5/29/02** | **12/18/01** |
| **Page No. in Reference 4** | **251, 281** | **283, 301** | **307, 323** | **331, 349** | **353, 370** | **373, 403** | **405, 434** | **457** | **303, 323** |
| **Page No. in Reference 41** | **4** | **5** | **7** | **8** | **9** | **10** | **28** | **17** | **6** |
| Arsenic | 0.0182 (MRL = 0.00500) | 0.0412 (MRL = 0.00500) | 0.338 (MRL = 0.00500) | 0.124 (MRL = 0.00500) | 0.108 (MRL = 0.00500) | 0.0662 (MRL = 0.00500) | 0.0681 (MRL = 0.00500) | 0.0300 (MRL = 0.0100) | 0.0464 (MRL = 0.00500) |
| Cadmium | 0.459 (MRL = 0.00200) | 0.562 (MRL = 0.00200) | 0.981 (MRL = 0.00200) | 0.707 (MRL = 0.00200) | 0.528 (MRL = 0.00200) | 0.427 (MRL = 0.00200) | 0.492 (MRL = 0.00200) | 0.472 (MRL = 0.00400) | 0.470 MRL = 0.00200) |
| Copper | 9.29 (MRL = 0.00500) | 15.3 (MRL = 0.0500) | 83.2 (MRL = 0.0500) | 42.5 (MRL = 0.0500) | 35.3 (MRL = 0.0500) | 26.8 (MRL = 0.0500) | 23.6 (MRL = 0.0250) | 17.2 (MRL = 0.0100) | 59.9 (MRL = 0.0500) |
| Lead | 0.0115 (MRL = 0.00500) | 0.00720 (MRL = 0.00500) | 0.0293 (MRL = 0.00500) | 0.0446 (MRL = 0.00500) | 0.0509 (MRL = 0.00500) | 0.0484 (MRL = 0.00500) | 0.0261 (MRL = 0.00500) | 0.0216 (MRL = 0.0100) | 0.0313 (MRL = 0.00500) |
| Manganese | 3.86 (MRL = 0.00500) | 4.36 (MRL = 0.00500) | NA | 2.90 (MRL = 0.00500) | 1.94 (MRL = 0.00500) | 1.76 (MRL = 0.00500) | 2.60 JL (MRL = 0.00500) | 3.00 (MRL = 0.0100) | NA |
| Nickel | 0.154 (MRL = 0.00500) | 0.174 (MRL = 0.00500) | 0.107 (MRL = 0.00500) | 0.112 (MRL = 0.00500) | 0.0734 (MRL = 0.00500) | 0.0628 (MRL = 0.00500) | 0.0972 (MRL = 0.00500) | 0.114 (MRL = 0.0100) | 0.0700 (MRL = 0.00500) |
| Zinc | 168 (MRL = 0.250) | 168 (MRL = 0.200) | 210 (MRL = 0.250) | 157 (MRL = 0.250) | 124 (MRL = 0.100) | 103 (MRL = 0.500) | 143 (MRL = 0.120) | 133 (MRL = 0.0500) | 76.0 (MRL = 0.200) |

Key:

mg/L = milligrams per Liter.
MRL = Method Reporting Limit.
NA = Not analyzed.
No. = Number.J = Value is estimated, but the presence of the substance is not in doubt
L = Low bias.

### 2.4.2 Hazardous Waste Quantity
#### 2.4.2.1.1 Hazardous Constituent Quantity

Available data are insufficient to document a hazardous constituent quantity (Ref. 1, p. 51590, Section 2.4.2.1.1).

Hazardous Constituent Quantity (C): NS

#### 2.4.2.1.2 Hazardous Wastestream Quantity

Available data are insufficient to document a hazardous wastestream quantity (Ref. 1, p. 51591, Section 2.4.2.1.2).

Hazardous Wastestream Quantity (W): NS

#### 2.4.2.1.3 Volume

Flow rates for the Formosa 1 and Silver Butte adits have been collected from June 1999 through May 2002 (Ref. 4, p. 29; Ref. 6, p. 29; Ref. 9, p. 92). Flow rates for the Formosa 1 Adit ranged from 0.0029 cfs to 0.4240 cfs (Ref. 4, p. 29, Ref. 9, p. 92). Flow rates for the Silver Butte Adit ranged from 0 cfs to 0.0439 cfs (Ref. 4, p. 29, Ref. 9, p. 92). The flow rate of the Formosa 1 Adit as measured in 1999 during the Environmental Site Assessment was 1 gpm (Ref. 6, p. 29). The adits are known to have flowed since as early as 1994; however, due to seasonal fluctuation, and limited sampling information, flow from this date to the present cannot be established with confidence. As a conservative measure, the volume of flow for these adits for one day has been estimated . In determining this estimate, the day with the highest flow rate recorded was used. Information below shows the conversion for each adit from cfs to gallons per day; and the total volume assigned to this source.

**Formosa 1 Adit**

0.4240 cfs x 7.48 gallons per second (Ref. 37) = 3.17152 gallons per second (gps)
3.17152 gps x 60 seconds per minute = 190.2912 gallons per minute
190.2912 gallons per minute x 60 minutes per hour = 11,417.472 gallons per hour
11,417.472 gallons per hour x 24 hours per day = 274,019.328 gallons per day

**Silver Butte Adit**

0.0439 cfs x 7.48 gps (Ref. 37) = 0.328372 gps
0.328372 gps x 60 seconds per minute = 19.70232 gallons per minute
19.70232 gallons per minute x 60 minutes per hour = 1,182.1392 gallons per hour
1,182.1392 gallons per hour x 24 hours per day = 28,371.3408 gallons per day

**Total volume for Source 4:**

274,019.328 gallons per day from the Formosa 1 Adit + 28,371.3408 gallons per day from the Silver Butte Adit = 302,390.6688 gallons per day from both adits. This value is converted to cubic yards as follows:

302,390.6688 gallons per day / 200 gallons per cubic yard (Ref. 1, p. 51591) = 1,511.953344 cubic yards per day

**The hazardous waste quantity value for this source is:**

1,511.953344 cubic yards / 2.5 for source type other (Ref. 1, p. 51591) = 604.7813376
604.7813376 rounded to the nearest integer = 605

Volume Assigned Value (V): 605
Ref. 1, p. 51591, Table 2-5

#### 2.4.2.1.4 Area

Since the volume measure was determined, the area measure was not evaluated (Ref. 1, p 51591, Section 2.4.2.1.4).

Area Assigned Value (A): 0

Source Hazardous Waste Quantity Factor Value: 605

## SOURCE DESCRIPTION

### 2.2 SOURCE CHARACTERIZATION

Number of Source: 5

Name and Description of the Source: 404 Adit discharge (other)

Source 5 consists of water discharging from the 404 Adit at the Formosa Mine to an unnamed tributary of South Fork Middle Creek (Ref. 6, p. 4; Figure 1). After mining operations ceased in 1993, Formosa Exploration, Inc., backfilled the adits with the most reactive material found at the Formosa Mine which included mill tailings and high-grade-crushed ore (Ref. 6, p. 8). Additionally, 750 tons of crushed ore which had been stockpiled north of the former mill was used to backfill the adits (Ref. 8, p. 14). In total, approximately 53,400 cubic yards of material were backfilled into the mine workings (Ref. 21, pp. 29, 350 through 361). In 1999, the flow rate of the 404 Adit was measured to be 0.1 gpm (Ref. 6, p. 29).

The EPA has not conducted an SI at the Formosa Mine; however, two privately funded investigations have been conducted, the Environmental Site Assessment conducted by Dynamac Corporation in 2000 (Ref. 6) and the Remedial Investigation conducted by Oregon Department of Environmental Quality and the Bureau of Land Management in 2000 (Ref. 5). Data from these investigations will be used to document the presence of hazardous substance in adit discharges.

**Final Site Assessment (Ref. 6):** In October 1999, fieldwork for an environmental site assessment was conducted (Ref. 6, p. ES-1). During this field work, a surface water sample, SB-SW-404, was collected from the 404 Adit (Ref. 6, pp. 27 and 28). This sample was collected directly from the adit discharge (Ref. 6, p. 27). A workplan was developed for this fieldwork (Ref. 10). The sample was sent under chain-of-custody to a fixed laboratory for analysis of TAL metals using EPA Method 6010B (Ref. 6, p. 160; Ref. 10, p. 26). Hazardous substances detected at significant concentrations in the adit water include barium and manganese (see Table 10 below)

**Remedial Investigation (Ref. 5):** A remedial investigation was conducted from 1999 to 2000 (Ref. 5, p. 7). Surface water samples were collected from the 404 Adit on January 25, 2000 and March 23, 2000 (Ref. 5, pp. 5 and 11; Ref. 16, pp. 3 and 53). The surface water samples were collected by placing the open bottle upstream and allowing it to fill (Ref. 5, p. 10; Ref. 23, p. 82). Since method reporting limits are only provided for the sample results collected on March 23, 2000, only data from this date will be used to determine hazardous substances associated with this adit. The sample was sent under chain-of-custody to a fixed laboratory for analysis of dissolved metals using EPA 200 Series method (Ref. 16, pp. 3). Hazardous substances detected in the adit water sample include barium, cadmium, chromium, cobalt, copper, lead, manganese, selenium, and zinc (see Table 11 below).

Location of the source, with reference to a map:
The 404 Adit is located near the headwaters of an unnamed tributary to the South Fork of Middle Creek (Ref. 6, p. 28).

Containment:

Release to Surface Water via Overland Migration and/or Flood: A surface water containment factor value of 10 is assigned based on evidence of hazardous substance migration from the source area [i.e., the 404 Adit is a flowing adit and water from this adit contains hazardous substances (Ref. 6, p. 29; Ref. 1, p. 51609, Table 4-2); and Tables 10 and 11 below].

Containment Value: 10

### 2.2.2 Hazardous Substances

Samples of the backfilled material are not known to have been collected; however, water emerging from the 404 Adit has been sampled. Tables 10 and 11 below provide hazardous substances associated with Source 5 based on the two earlier field sampling events discussed in Section 2.2.

Although not required when determining the hazardous substances associated with a waste source, only adit water sample results from the Environmental Site Assessment meeting observed release by chemical analysis criteria (see Ref. 1, p. 51589) will be included in Table 10 below. Sample SB-SW-SFU will be used as the background sample for sample SB-SW-404 for this purpose. This sample was collected from the headwaters of South Fork Middle Creek (Ref. 6, p. 28).

**Table 10 Hazardous Substances Associated with Source 5 from the Environmental Site Assessment (units = mg/L)**

| Sample Number | SB-SW-SFU | SB-SW-404 |
|---|---|---|
| Location | Background | 404 Adit |
| Reference | Ref. 6, pp. 120, 121, 159, 164 through 167; Ref. 40, pp. 21, 22 | Ref. 6, pp. 118, 119, 160, 164 through 167; Ref. 40, pp. 19, 20 |
| Barium | <0.0040 (MRL = 0.0040) | 0.046 (MRL = 0.010) |
| Manganese | <0.010 (MRL = 0.010) | 0.16 (MRL = 0.010) |

Key:

mg/L = milligrams per liter.
MRL = Method reporting limit.
< = The material was analyzed for but was not detected.

Table 11 below provides hazardous substances associated with Source 5 based on sample results from the Remedial Investigation (Ref. 5; Ref. 16).

| **Table 11** | **Hazardous Substances Associated with Source 5 from the Remedial Investigation (units = mg/L)** |
|---|---|
| **Sample Name** | **404 Adit** |
| **Page No. in Reference 16** | **3, 5, 6, and 33** |
| **Analyte** | |
| Barium | 0.0349 (MRL = 0.00200) |
| Cadmium | 0.00180 (MRL = 0.00100) |
| Chromium | ND |
| Cobalt | 0.00287 (MRL = 0.00200) |
| Copper | 0.268 (MRL = 0.00200) |
| Lead | 0.00362 (MRL = 0.00100) |
| Manganese | 0.182 (MRL = 0.0100) |
| Selenium | 0.00238 (MRL = 0.00100) |
| Zinc | 0.415 (MRL = 0.00500) |

Key:

No. = Number.
mg/L = milligrams per Liter.
MRL = Method reporting limit.
ND = Not detected.

### 2.4.2 Hazardous Waste Quantity

#### 2.4.2.1.1 Hazardous Constituent Quantity

Available data are insufficient to document a hazardous constituent quantity (Ref. 1, p. 51590, Section 2.4.2.1.1).

Hazardous Constituent Quantity (C): NS

#### 2.4.2.1.2 Hazardous Wastestream Quantity

Available data are insufficient to document a hazardous wastestream quantity (Ref. 1, p. 51591, Section 2.4.2.1.2).

Hazardous Wastestream Quantity (W): NS

#### 2.4.2.1.3 Volume

The flow rate of the 404 Adit as measured in 1999 during the Environmental Site Assessment was 0.1 gpm (Ref. 6, p. 29). The adit is known to have flowed since as early as 1994; however, due to seasonal fluctuation, and limited sampling information, flow from this date to the present cannot be established with confidence. As a conservative measure, the volume of flow for this adit for one day has been estimated. Information below shows the conversion from gpm to gallons per day; and the total volume assigned to this source.

**404 Adit**

0.1 gpm x 60 minutes per hour = 6 gallons per hour
6 gallons per hour x 24 hours per day = 144 gallons per day

**Total volume for Source 5:**

144 gallons per day from the 404 Adit is converted to cubic yards as follows:

144 gallons per day / 200 gallons per cubic yard (Ref. 1, p. 51591) = 0.72 cubic yards per day

**The hazardous waste quantity value for this source is:**

0.72 cubic yards / 2.5 for source type other (Ref. 1, p. 51591) = 0.288

Volume Assigned Value (V): 0.288
Ref. 1, p. 51591, Table 2-5

#### 2.4.2.1.4 Area

Since the volume measure was determined, the area measure was not evaluated (Ref. 1, p 51591, Section 2.4.2.1.4).

Area Assigned Value (A): 0

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Source Hazardous Waste Quantity Factor Value: 0.288

SUMMARY OF SOURCE DESCRIPTIONS

| Source Number | | Source Hazardous Waste Quantity Value [a] | Containment Value for Surface Water [b] |
|---|---|---|---|
| 1. | Formosa 1 Adit and Silver Butte Adit Waste Rock Piles | 3,040 | 10 |
| 2. | 404 Adit Waste Rock Pile | 8 | 10 |
| 3. | Encapsulation Mound | 10,606 | 10 |
| 4. | Formosa 1 Adit and Silver Butte Adit | 605 | 10 |
| 5. | 404 Adit | 0.288 | 10 |
| **Total** | | **14,259.288** | |

[a] See section 2.2 of this document.
[b] Ref. 1, pp. 51609, 51610, Table 4-2.

## 4.1 OVERLAND/FLOOD MIGRATION COMPONENT

### 4.1.1.1 Definition of Hazardous Substance Migration Path for Overland/Flood Component

The Formosa Mine is located within the South Umpqua watershed (Ref. 5, p. 7). Acidic water flows from the Formosa 1 and Silver Butte adits (Ref. 4, p. 8). Three overland probable points of entry (PPEs) are present at the Formosa Mine (Figure 1; Ref. 35, pp. 2, 3). PPE 1 is associated with the flow from the Formosa 1 Adit and the Silver Butte Adit; and runoff from their associated waste rock piles (Figure 1). The Formosa 1 Adit and Silver Butte Adit flowed to one of the upper branches of Middle Creek (Ref. 35, pp. 2, 3). From PPE 1, Middle Creek flows 13.25 miles to its confluence with Cow Creek (Ref. 39, pp. 2, 4). The TDL concludes in Cow Creek 1.75 miles downstream (Ref. 39, pp. 2, 4).

PPE 2 is associated with runoff from the encapsulation mound (Figure 1). Overland runoff from the encapsulation mound flows to the South Fork of Middle Creek (Ref. 6, p. 35; Figure 1). South Fork Middle Creek flows approximately 4.41 miles downstream to the confluence with Middle Creek (Ref. 39, pp. 2, 4). The TDL continues in Middle Creek for 10.38 miles to the confluence of Cow Creek, and concludes in Cow Creek approximately 0.21 mile downstream (Ref. 39, pp. 2, 4).

PPE 3 is associated with the flow from the 404 Adit and runoff from its associated waste rock pile (Figure 1; Ref. 12, p. 3-3). The 404 Adit and runoff from its associated waste rock pile flow to a tributary to the South Fork Middle Creek (Figure 1). The unnamed tributary flows approximately 0.92 mile to the confluence with South Fork Middle Creek (Ref. 39, pp. 2, 4). The South Fork Middle Creek flows 1.99 miles to the confluence with Middle Creek (Ref. 39, pp. 2, 4). The TDL continues in Middle Creek for 10.38 miles to the confluence of Cow Creek, and concludes in Cow Creek approximately 1.71 miles downstream (Ref. 39, pp. 2, 4).

Middle Creek and South Fork Middle Creek combine within the TDL (Ref. 3; Figures 2, 3, and 4)

Flow rates for the Formosa 1, Silver Butte, and 404 adits have been collected from June 1999 through May 2002 (Ref. 4, p. 29; Ref. 6, p. 29; Ref. 9, p. 92). Flow rates for the Formosa Adit ranged from 0.0029 cfs to 0.4240 cfs (Ref. 4, p. 29; Ref. 9, p. 92). Flow rates for the Silver Butte Adit ranged from 0 cfs to 0.0439 cfs (Ref. 4, p. 29; Ref. 9, p. 92). The flow rate at the 404 Adit as measured in 1999 was 0.1 gpm (Ref. 6, p. 29). Based on the USGS topographic map, Middle Creek and South Fork Middle Creek are perennial streams (Ref. 3). This is supported by observations by BLM staff at the site (Ref. 43). The average annual precipitation as measured at Riddle, Oregon, which is located approximately 18 miles from the Formosa Mine is 31.49 inches (Ref. 34, p. 1). Flow rates for the South Fork Middle Creek and Middle Creek are estimated to be between 10 and 100 cfs (Ref. 12, p. 3-3). The average annual flow rate from 2003 for Cow Creek, as measured near Riddle, Oregon is 629 cfs (Ref. 13, p. 1). Riddle, Oregon is located 18 miles downstream of the confluence of Middle Creek and Cow Creek (Ref. 12, p. 3-3). The flow rate of Cow Creek is likely to vary between the end of the TDL and the measurement point at Riddle, Oregon. For this reason, a flow rate for Cow Creek of greater than 100 to 1,000 cfs will be used in this document.

Prior to reclamation efforts, Middle Creek and South Fork Middle Creek contained large numbers of Coho salmon and rainbow trout (Ref. 17, p. 2). Based on information collected during a fish sampling event conducted by the U.S. Bureau of Land Management in May 2003,

no fish were noted on South Fork Middle Creek at locations 3.0 and 4.7 within the TDL (Ref. 28, pp. 3 and 4; Figure 2).

In 2004, it was documented that heavy metals concentrations in Middle Creek and South Fork Middle Creek exceeded aquatic life standards by a factor of between 10 and 100, severely degrading habitat for aquatic receptors including macroinvertebrates, coastal steelhead trout, and Oregon coastal Coho salmon (Ref. 21, p. 1). Middle Creek is designated as a Tier 1 Key Watershed under the Northwest Forest Plan (Ref. 6, p. 7; Ref. 33, p. 2). A Tier 1 Key Watershed serves as refugia crucial for maintaining and recovering habitat for at-risk stocks of anadromous salmonids and resident fish species (Ref. 33, p. 2). Once restored, Middle Creek would act as a migratory pathway and feeding area critical for the maintenance of anadromous fish species within this river reach in which the fish would spend extended periods of time (Ref. 33, p. 2). Finally, it has been documented that fishing is occurring on Middle Creek and Cow Creek within the zone of actual contamination (Figures 2, 3, and 4; Ref. 15, p. 1; 2; Ref. 18, p. 1; Ref. 31, p. 1). Discharges from the Formosa Mine probably have been negatively affecting Middle Creek for approximately 80 years (Ref. 22, p. 18).

**4.1.2.1 LIKELIHOOD OF RELEASE**
**4.1.2.1.1 Observed Release**

Direct Observation
- Basis for Direct Observation

Discharges from the Formosa Mine probably have been negatively affecting Middle Creek for approximately 80 years (Ref. 22, p. 18). During operation of the Formosa Mine, storm water discharges contaminated Middle Creek with an estimated 20 tons of pyrite and other metal-bearing sulfide minerals and was spread over about 4,000 feet of stream length (Ref. 22, p. 18; Ref. 30, p. 2; Ref. 8, pp. 1, 24, 25). Small quantities of the material were visible one mile downstream and the creek was effectively "dead" with no signs of life farther down the stream (Ref. 22, p. 18). A fish survey in the summer of 1993 showed no fish in Middle Creek above the confluence with the South Fork of Middle Creek (Ref. 22, p. 18). The sulfides were removed from Middle Creek; the process also removed all organic material from the stream bed which may have filtered metals from the stream (Ref. 22, p. 18). On May 11, 1994, after the cleanup, the pH in Middle Creek ranged from 7.2 to 7.5 while the pH in the South Fork of Middle Creek was 7.4 (Ref. 22, p. 18). On June 8, 1994, one salamander was reported in Middle Creek, but there were no macroinvertebrates and the pH was 6.6 in Middle Creek (Ref. 22, p. 18).

During the winter of 1995 – 1996, the water from the Formosa Adit flowed out of the adit to the surface then down the roadside ditch, through a culvert under the road and directly into Middle Creek (Ref. 30, p. 3). That hazardous substances are associated with the Adit flow is documented earlier in this document in the discussion of Source 4. This is evidence that an additional observed release by direct observation occurred during the winter of 1995 – 1996.

Chemical Analysis
- Basis for Chemical Analysis

Although the EPA has not conducted an SI at the Formosa Mine, several privately funded environmental investigations have been performed at the Formosa Mine. Data from the supplemental remedial investigation performed by Hart Crowser, Inc, in 2002 (Ref. 4), the remedial investigation performed by the BLM and ODEQ in 2000 (Ref. 5), and the site assessment performed by Dynamac Corporation in 2000 (Ref. 6) will be used to document an observed release by chemical analysis. Additional corroboration of this observed release based on earlier sampling events is provided in the attribution section below.

**Supplemental Remedial Investigation (Ref. 4):** This investigation was conducted to supplement the remedial investigation that was conducted by the U.S. BLM (Ref. 4, p. 6). During the investigation, surface water samples were collected from various locations along Middle Creek and South Fork Middle Creek as well as a sample from a nearby tributary (T1) (Ref. 4, pp. 14, 33 through 42, 58). The surface water samples were collected by dipping a collection bottle into the water and using a peristaltic pump to transfer the water through a 0.045 micron filter into the laboratory supplied bottle, the samples were then placed in a cooler with ice (Ref. 4, p. 72). The samples were sent under chain-of-custody to a fixed laboratory for analysis of dissolved metals using EPA Method 6010B (Ref. 4, pp. 20, 454, 474, 506).

Two samples (SF1 and T1) were collected outside of the influence of the Formosa Mine (Ref. 12, p. 2-14). Sample SF1 was collected on South Fork Middle Creek and sample T1 was collected on a tributary to this creek (Ref. 4, p. 58). Table 12 below provides analytical information on surface water samples meeting observed release criteria. Blank cells in the table indicate the sample result does not meet observed release criteria.

**Remedial Investigation (Ref. 5):** During this investigation, surface water samples were collected from 15 locations on Middle Creek, South Fork Middle Creek, and Cow Creek on March 23, 2000 (Ref. 5, pp. 54 through 57). The surface water samples were collected by placing the open bottle up stream and allowing it to fill (Ref. 5, p. 10; Ref. 23, p. 82). The samples were sent under chain-of-custody to a fixed laboratory for dissolved metals analysis by methods 200.7 and 200.8 (Ref. 16, pp. 1, 2, 3, 4).

Three samples [MREF1 on Middle Creek, SFREF1 on the South Fork of Middle Creek, and Cow Creek #1 on Cow Creek) serve as the background samples for their respective streams since they were collected from locations upgradient of stream confluences and outside of site influences (Ref. 5, pp. 11 and 12). Table 13 below provides analytical information on surface water samples meeting observed release criteria. Blank cells in the table indicate the sample result does not meet observed release criteria.

**Final Site Assessment Report (Ref. 6):** In October 1999, three locations were sampled on Middle Creek (Ref. 6, pp. 27 and 28). Sample location SB-SW-MA was collected from the upper reaches of Middle Creek (Ref. 6, p. 27). Additionally, samples from two co-located surface water/sediment locations (SB-SW-A4/SB-SED-A4 and SB-SW-A9/SB-SED-A9) were collected from Middle Creek (Ref. 6, pp. 27, 28). A workplan was developed for this field work (Ref. 10). The samples were sent under chain-of-custody to a fixed laboratory for analysis of TAL metals using method 6010B for surface water samples and methods 6010B, 7471A (mercury), and 4500-CN (amendable cyanide) for sediment samples (Ref. 6, pp. 159,161; Ref. 10, p. 26). Table 14 below provides analytical information on surface water samples meeting observed release criteria. Blank cells in the table indicate the sample result does not meet observed release criteria.

**Table 12 Surface Water Samples-Dissolved Metals- Documenting an Observed Realse to Surface Water from the Supplemental Remedial Investigation (units = mg/L)**

| Station ID | SF1 | T1 | A9 | A14 | MXR | MXR |
|---|---|---|---|---|---|---|
| Sample Date | 6/27/02 | 6/27/02 | 5/29/02 | 5/29/02 | 5/28/02 | 5/29/02 |
| Reference | Ref. 4, pp. 478, 506; Ref. 41, p. 23 | Ref. 4, pp. 479, 506; Ref. 41, p. 24 | Ref. 4, pp. 461, 474; Ref. 41, p. 19 | Ref. 4, pp. 462, 474; Ref. 41, p. 20 | Ref. 4, pp. 437, 454; Ref. 41, p. 11 | Ref. 4, pp. 463, 474; Ref. 41, p. 21 |
| Distance (Ref. 39, p. 2) | Confluence with South Fork Middle Creek = 0.03 mile | Confluence with South Fork Middle Creek = 0.11 mile | PPE 1 = 0.39 mile | PPE 1 = 0.56 mile | PPE 1 = 0.76 mile | |
| Location | Background | | Middle Creek | | | |
| Analyte | | | | | | |
| Cadmium | ND (MRL = 0.00250) | ND (MRL = 0.00250) | 0.0736 (MRL = 0.00400) | 0.0320 (MRL = 0.00400) | 0.0184 (MRL = 0.00400) | 0.0158 (MRL = 0.00400) |
| Copper | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 6.94 (MRL = 0.0100) | 2.60 (MRL = 0.0100) | 0.464 (MRL = 0.0100) | 0.438 (MRL 0.0100) |
| Manganese | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 1.65 (MRL = 0.0100) | 0.628 (MRL = 0.0100) | 0.151 (MRL = 0.0100) | 0.145 (MRL = 0.0100) |
| Nickel | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 0.0356 (MRL = 0.0100) | 0.0172 (MRL = 0.0100) | 0.0130 (MRL = 0.0100) | 0.0102 (MRL = 0.0100) |
| Zinc | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 37.4 (MRL = 0.0100) | 7.76 (MRL = 0.0100) | 3.58 (MRL = 0.0100) | 3.48 (MRL = 0.0100) |

Note:

Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.

mg/L = Milligrams per liter.

MRL = Method Reporting Limit.

ND = Not detected.

**Table 12 Surface Water Samples-Dissolved Metals- Documenting an Observed Realse to Surface Water from the Supplemental Remedial Investigation (units = mg/L)**

| Station ID | SF1 | T1 | M1 | M2 | SF0 | SF0 |
|---|---|---|---|---|---|---|
| Sample Date | 6/27/02 | 6/27/02 | 5/28/02 | 5/28/02 | 5/28/02 | 6/27/02 |
| Reference | Ref. 4, pp. 478, 506; Ref. 41, p. 23 | Ref. 4, pp. 479, 506; Ref. 41, p. 24 | Ref. 4, pp. 438, 454; Ref. 20, p. 1; Ref. 41, p. 12 | Ref. 4, pp. 439, 454; Ref. 20, p. 1; Ref. 41, p. 13 | Ref. 4, pp. 440, 454; Ref. 41, p. 14 | Ref. 4, pp. 477, 506; Ref. 41, p. 22 |
| Distance (Ref. 39, p. 2) | Confluence with South Fork Middle Creek = 0.03 mile | Confluence with South Fork Middle Creek = 0.11 mile | PPE 1 = 2.68 miles | PPE 1 = 3.17 miles<br>PPE 2 = 4.71 miles<br>PPE 3 = 3.21 miles | PPE 2 = 0.80 mile | |
| Location | Background | | Middle Creek | | South Fork Middle Creek | |
| Analyte | | | | | | |
| Cadmium | ND (MRL = 0.00250) | ND (MRL = 0.00250) | 0.00420 (MRL = 0.00400) | | 0.00520 (MRL = 0.00400) | 0.0025 (MRL = 0.00250) |
| Copper | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 0.0282 (MRL = 0.0100) | 0.0218 (MRL = 0.0100) | 0.126 (MRL = 0.0100) | 0.0435 (MRL = 0.00620) |
| Manganese | ND (MRL = 0.00620) | ND (MRL = 0.00620) | | | 0.0678 (MRL = 0.0100) | 0.0124 (MRL = 0.00620) |
| Nickel | ND (MRL = 0.00620) | ND (MRL = 0.00620) | | | | |
| Zinc | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 0.342 (MRL = 0.0100) | 0.188 (MRL = 0.0100) | 1.36 (MRL = 0.0100) | 0.754 (MRL = 0.00620) |

Note:

Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
mg/L = Milligrams per liter.
MRL = Method Reporting Limit.

ND = Not detected.

**Table 12 Surface Water Samples-Dissolved Metals- Documenting an Observed Realse to Surface Water from the Supplemental Remedial Investigation (units = mg/L)**

| Station ID | SF1 | T1 | SF4 | SF5 |
|---|---|---|---|---|
| Sample Date | 6/27/02 | 6/27/02 | 5/28/02 | 5/28/02 |
| Reference | Ref. 4, pp. 478, 506; Ref. 41, p. 23 | Ref. 4, pp. 479, 506; Ref. 41, p. 24 | Ref. 4, pp. 441, 454; Ref. 41, p. 15 | Ref. 4, pp. 442, 454; Ref. 41, p. 16 |
| Distance (Ref. 39, p. 2) | Confluence with South Fork Middle Creek = 0.03 mile | Confluence with South Fork Middle Creek = 0.11 mile | PPE 2 = 3.11 miles PPE 3 = 1.61 miles | PPE 2 = 4.35 miles PPE 3 = 2.85 miles |
| Location | Background | | South Fork Middle Creek | |
| Analyte | | | | |
| Cadmium | ND (MRL = 0.00250) | ND (MRL = 0.00250) | | |
| Copper | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 0.0202 (MRL = 0.0100) | 0.0136 (MRL = 0.0100) |
| Manganese | ND (MRL = 0.00620) | ND (MRL = 0.00620) | | |
| Nickel | ND (MRL = 0.00620) | ND (MRL = 0.00620) | | |
| Zinc | ND (MRL = 0.00620) | ND (MRL = 0.00620) | 0.180 (MRL = 0.0100) | 0.121 (MRL = 0.0100) |

Note:

Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
mg/L = Milligrams per liter.
MRL = Method Reporting Limit.

ND = Not detected.

**Table 13 Surface Water Samples Documenting an Observed Release from the Remedial Investigation (units = mg/L)**

| Sample Location | S.F. Middle Creek Site SF2 | S.F. Middle Cr. Site 0 | S.F. Middle Site 3 | S.F. Middle Site 4 | S.F.Middle Cr. Site 5 |
|---|---|---|---|---|---|
| **Reference** | **Ref. 16, pp. 2, 28; Ref. 20, p. 1** | **Ref. 16, pp. 2, 27; Ref. 20, p. 1** | **Ref. 16, pp. 2, 26, 27; Ref. 20, p. 1** | **Ref. 16, pp. 2, 26; Ref. 20, p. 1** | **Ref. 16, pp. 2, 25; Ref. 20, p. 1** |
| **Distance (Ref. 39, p. 2)** | **Confluence with South Fork Middle Creek = 0.65 mile** | **PPE 2 = 0.48 mile** | **PPE 2 = 1.22 miles** | **PPE 2 = 2.75 miles PPE 3 = 1.25 miles** | **PPE 2 = 4.30 miles PPE 3 = 2.80 miles** |
| **Location** | **Background** | **South Fork Middle Creek** | | | |
| **Analyte** | | | | | |
| Cadmium | ND (MRL = 0.00100) | 0.00835 (MRL = 0.00100) | 0.00303 (MRL = 0.00100) | 0.00123 (MRL = 0.00100) | |
| Chromium | ND (MRL = 0.00100) | | | | |
| Cobalt | ND (MRL = 0.00200) | | | | |
| Copper | 0.00290 (MRL = 0.00200) | 0.302 (MRL = 0.00200) | 0.120 (MRL = 0.00200) | 0.0493 (MRL = 0.00200) | 0.0331 (MRL = 0.00200) |
| Lead | ND (MRL = 0.00100) | | | | |
| Manganese | 0.0110 (MRL = 0.0100) | 0.228 (MRL = 0.0100) | 0.0820 (MRL = 0.0100) | 0.0350 (MRL = 0.0100) | |
| Nickel | ND (MRL = 0.00200) | 0.00688 (MRL = 0.00200) | 0.00260 (MRL = 0.00200) | | |
| Selenium | ND (MRL = 0.00100) | 0.00198 (MRL = 0.00100) | | | |
| Zinc | 0.0149 (MRL = 0.00500) | 2.20 (MRL = 0.371) | 0.766 (MRL = 0.00500) | 0.306 (MRL = 0.00500) | 0.231 (MRL = 0.00500) |

Note: Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
mg/L = milligrams per liter.
MRL = Method Reporting Limit.
ND = Not detected.

**Table 13 Surface Water Samples Documenting an Observed Release from the Remedial Investigation (units = mg/L)**

| Sample Location | Middle Creek F-1 | A9 | Site MXR | Middle Creek Site 1 | Middle Creek Site 2 | Middle Creek Site 3 | Middle Creek Site 5 |
|---|---|---|---|---|---|---|---|
| **Reference** | **Ref. 16, pp. 2, 29; Ref. 20, p. 1** | **Ref. 16, pp. 1, 18; Ref. 20, p. 1** | **Ref. 16, pp. 2, 24, 25; Ref. 20, p. 1** | **Ref. 16, pp. 2, 24; Ref. 20, p. 1** | **Ref. 16, pp. 2, 22; Ref. 20, p. 1** | **Ref. 16, pp. 2, 21; Ref. 20, p. 1** | **Ref. 16, pp. 2, 20; Ref. 20, p. 1** |
| **Distance (Ref. 39, p. 2)** | **Confluence with Middle Creek = 0.03 mile** | **PPE 1 = 0.39 mile** | **PPE 1 = 0.76 mile** | **PPE 1 =2.68 miles** | **PPE 1 = 3.17 miles<br>PPE 2 = 4.71 miles<br>PPE 3 = 3.21 miles** | **PPE 1 = 7.02 miles<br>PPE 2 = 8.56 miles<br>PPE 3 = 7.06 miles** | **PPE 1 = 12.73 miles<br>PPE 2 = 14.27 miles<br>PPE 3 = 12.77 miles** |
| **Location** | **Background** | **Middle Creek** | | | | | |
| **Analyte** | | | | | | | |
| Cadmium | ND (MRL = 0.00100) | 0.133 (MRL = 0.00756) | 0.0315 (MRL = 0.00100) | 0.00344 (MRL = 0.00100) | 0.00154 (MRL = 0.00100) | | |
| Chromium | ND (MRL = 0.00100) | 0.00130 (MRL = 0.00100) | | | | | |
| Cobalt | ND (MRL = 0.00200) | 0.0169 MRL = 0.00200) | 0.00332 (MRL = 0.00200) | | | | |
| Copper | 0.00625 (MRL = 0.00200) | 8.69 (MRL = 0.200) | 1.07 (MRL = 0.0148) | 0.0743 (MRL = 0.00200) | 0.0435 (MRL = 0.00200) | 0.0195 (MRL = 0.00200) | |
| Lead | ND (MRL = 0.00100) | 0.00100 (MRL = 0.00100) | | | | | |
| Manganese | ND (MRL = 0.0100) | 1.33 (MRL = 0.0100) | 0.263 (MRL = 0.0100) | 0.0160 (MRL = 0.0100) | 0.0170 (MRL = 0.0100) | | |
| Nickel | ND (MRL = 0.00200) | 0.0424 (MRL = 0.00200) | 0.0141 (MRL = 0.00200) | 0.00313 (MRL = 0.00200) | | | |
| Selenium | ND (MRL = 0.00100) | 0.00421 (MRL = 0.00100) | | | | | |
| Zinc | 0.0132 (MRL = 0.00500) | 32.8 (MRL = 0.500) | 8.12 (MRL = 0.500) | 0.819 (MRL = 0.00500) | 0.354 (MRL = 0.00500) | 0.175 (MRL = 0.00500) | 0.0836 (MRL = 0.00500) |

Note: Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
mg/L = milligrams per liter.
MRL = Method Reporting Limit.
ND = Not detected.

## Table 13. Surface Water Samples Documenting an Observed Release from the Remedial Investigation (units = mg/L)

| Sample Location | Cow Cr. Site 1 | Cow Cr. Site 2 |
|---|---|---|
| **Reference** | **Ref. 16, pp. 3, 30; Ref. 20, p. 1** | **Ref. 16, pp. 3, 30, 31; Ref. 20, p. 1** |
| **Distance (Ref. 39, p. 2)** | **Confluence with Middle Creek = 0.06 mile** | **PPE 1 = 13.39 miles<br>PPE 2 = 14.95 miles<br>PPE 3 = 13.40 miles** |
| **Location** | **Background** | **Cow Creek** |
| **Analyte** | | |
| Cadmium | ND (MRL = 0.00100) | |
| Chromium | 0.00106 (MRL = 0.00100) | |
| Cobalt | ND (MRL = 0.00200) | |
| Copper | ND (MRL = 0.00200) | 0.00205 (MRL = 0.00200) |
| Lead | ND (MRL = 0.00100) | |
| Manganese | ND (MRL = 0.00100) | |
| Nickel | 0.00264 (MRL = 0.00200) | |
| Selenium | ND (MRL = 0.00100) | |
| Zinc | ND (MRL = 0.00500) | 0.0496 (MRL = 0.00500) |

Note: Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
mg/L = milligrams per liter.
MRL = Method Reporting Limit.
ND = Not detected.

**Table 14** **Surface Water Samples Documenting an Observed Release from the Final Environmental Site Assessment (units = mg/L)**

| Sample Location | SB-SW-SFU | SB-SW-MA | SB-SW-A4 | SB-SW-A9 |
|---|---|---|---|---|
| Reference | Ref. 6, pp. 120, 121; Ref. 40, pp. 21, 22 | Ref. 6, pp. 115, 116; Ref. 40, pp. 16, 17 | Ref. 6, pp. 110, 111; Ref. 40, pp. 11, 12 | Ref. 6, pp. 113, 114; Ref. 40, pp. 14, 15 |
| Distance (Ref. 39, p. 2) | 0.02 mile from the Headwaters of South Fork Middle Creek | PPE 1 = 0.04 mile | PPE 1 = 0.09 mile | PPE 1 = 0.39 mile |
| Location | Background | Middle Creek | | |
| **Analyte** | | | | |
| Barium | <0.0040 (MRL = 0.0040) | 0.020 (MRL = 0.010) | 0.024 (MRL = 0.010) | 0.016 (MRL = 0.010) |
| Cadmium | <0.0010 (MRL = 0.0010) | 0.042 (MRL = 0.0010) | 0.032 (MRL = 0.0010) | 0.088 (MRL = 0.0010) |
| Cobalt | <0.010 (MRL = 0.010) | | | 0.017 (MRL = 0.010) |
| Copper | <0.010 (MRL = 0.010) | 2.6 (MRL = 0.010) | 2.1 (MRL = 0.010) | 7.3 (MRL = 0.010) |
| Manganese | <0.010 (MRL = 0.010) | 0.45 (MRL = 0.010) | 0.70 (MRL = 0.010) | 1.9 (MRL = 0.010) |
| Nickel | <0.010 (MRL = 0.010) | 0.025 (MRL = 0.010) | 0.017 (MRL = 0.010) | 0.024 (MRL = 0.010) |
| Zinc | <0.050 (MRL = 0.050) | 15 (MRL = 0.050) | 11 (MRL = 0.050) | 21 (MRL = 0.50) |

Note: Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
MRL = Method Reporting Limit.
mg/L = Milligrams per liter.
< = The material was analyzed for but was not detected.

**Table 15** **Sediment Samples Documenting an Observed Release from the Final Environmental Site Assessment (units = mg/kg)**

| Sample Location | SB-SED-SFU | SB-SED-A4 | SB-SED-A9 |
|---|---|---|---|
| Reference | Ref. 6, p. 134; Ref. 40, p. 25 | Ref. 6, p. 126; Ref. 40, p. 2 | Ref. 6, p. 128; Ref. 40, p. 2 |
| Distance (Ref. 39, p. 2) | 0.2 mile from the Headwaters of South Fork Middle Creek | PPE 1 = 0.09 mile | PPE 1 = 0.39 mile |
| Location | Background | Middle Creek | |
| Analyte | | | |
| Arsenic | <5.0 (MRL = 5.0) | 20 (MRL = 5.0) | 62 (MRL = 5.0) |
| Barium | 5.2 (MRL = 5.0) | 1200 (MRL = 5.0) | 850 (MRL = 5.0) |
| Copper | 44 (MRL = 5.0) | 420 (MRL = 5.0) | 620 (MRL = 5.0) |
| Lead | <5.0 (MRL = 5.0) | 12.0 (MRL = 5.0) | 40 (MRL = 5.0) |
| Mercury | <0.10 (MRL = 0.10) | 0.31 (MRL = 0.10) | |
| Zinc | 37 (MRL = 10) | 190 (MRL = 10) | 440 (MRL = 10) |

Note: Blank cells indicate the sample result does not meet observed release criteria.

Key:

ID = Identification.
mg/kg = milligrams per kilogram.
MRL = Method Reporting Limit.
< = The material was analyzed for but was not detected.

**Attribution:**

The Formosa Mine is a former copper and zinc mine with a majority of production occurring from 1927 through 1933 (Ref. 6, p. ES-1; Ref. 17, p. 1). The mine was again in operation by Formosa Exploration, Inc. from 1990 to 1993 and produced ore at a rate of 250 to 400 tons per day (Ref. 6, p. ES-1; Ref. 17, p. 1). After the mine closed in 1993, Formosa Exploration, under the direction of DOGAMI, conducted some reclamation efforts which included sealing the mine and capping the encapsulation mound (Ref. 6, p. ES-1). Sources at the site include waste rock piles, the encapsulation mound, and drainage from the closed adits (see sources section above; Section 2.2). Although the adits were sealed, acid mine drainage containing hazardous substances continues to seep and threaten the downstream water bodies (Ref. 6, p. ES-1). These sources are associated with the observed release substances (see sources section above; Section 2.2), and, as discussed in the source containment sections earlier in this document and in the previous section discussing observed releases by direct observation;, releases to surface water from these sources have occurred.

While there are other possible off site sources along Middle Creek and South Fork Middle Creek, they do not appear to be contributing to the observed release. This is suggested by the fact that there do not appear to be any contaminant concentration spikes immediately downstream of incoming tributaries that may contain additional sources of hazardous substance migration, such as quarries or other mines (Ref. 3; Ref. 5, pp. 34 through 37).

Although not used to document an observed release to the surface water migration pathway for this documentation record, earlier reports documented mine-related contamination in target locations. This earlier work is discussed below.

**Remedial Investigation (Ref. 5):** The potential for adverse impacts to adjacent water resources is limited to the Formosa, Silver Butte, and 404 Adits (Ref. 5, p. 7). Prior to operation of the Formosa Mine, sustaining populations of salmonids and intolerant macroinvertebrates were documented throughout most of Middle Creek and the South Fork Middle Creek; however, since the closure of Formosa Mine, few fish have been observed (Ref. 5, p. 14). Biological conditions have degraded substantially in Middle Creek and South Fork Middle Creek since the closure of the Formosa Mine in 1993, and are documented through the decline of macroinvertebrates in these water bodies downstream of the Formosa Mine (Ref. 5, p. 15). Relative to pre-Formosa Exploration activities, the density and number of macroinvertebrates downstream of the Formosa Mine have decreased (Ref. 5, p. 15). The macroinvertebrate study indicates the primary contaminant sources are located near the Formosa 1 Adit, the Silver Butte Adit, and the encapsulation mound (Ref. 5, p. 18). Copper and zinc have been documented at elevated concentrations in South Fork Middle Creek, Middle Creek, and Cow Creek (see Tables 12 through 15 above). Copper-zinc, in lethal concentrations, has been documented to act two to three times faster on fish than do metals singly (Ref. 5, p. 32). Although the concentrations of zinc and copper continue to decline in value further from the mine, there do not appear to be any spikes immediately downstream of incoming tributaries that may contain additional sources of hazardous substance migration such as quarries or other mines (Ref. 3; Ref. 5, pp. 34 through 37).

**Human Health and Ecological Baseline Risk Assessment (Ref. 19):** This investigation was conducted by Hart Crowser, Inc. on behalf of the ODEQ to evaluate the potential for adverse impacts to human health and the environment attributable to exposure to Formosa Mine-related contaminants (Ref. 19, pp. cover page, 7). The assessment drew on analytical data from earlier works, specifically the Dynamac Site Assessment Report, 2000; the BLM Remedial

Investigation Report, 2000; the Hart Crowser Data Evaluation Report, 2001; the Hart Crowser Supplemental Remedial Investigation Report, 2002; and loose tables provided by Mr. James Harvey, BLM Roseburg (Ref. 19, p. 167). The investigation concluded that the upper segment of Middle Creek receives high metals inputs under both high and low flow conditions and that unacceptable ecological conditions with regards to water quality are present during both high and low flow conditions for aquatic receptors including macroinvertebrates, resident fish, and Oregon Coast Coho salmon (Ref. 19, p. 68). The data suggest that unacceptable ecological conditions with regards to water quality are present for aquatic receptors including macroinvertebrates, resident fish, and Oregon Coast coho salmon under high flow conditions in Middle Creek (Ref. 19, p. 69).

Hazardous Substances Released

The hazardous substances found in observed releases to surface water bodies within the TDL are arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, and zinc.

### 4.1.3.2 WASTE CHARACTERISTICS
### 4.1.3.2.1 Toxicity/Persistence/Bioaccumulation

Table 16 below provides Human Food Chain Threat Waste Characteristics Factor Values for those hazardous substances present in sources at the Formosa Mine (see Section 2.2).

**Table 16 Human Food Chain Threat Waste Characteristics Factor Values**

| Hazardous Substance | Source | Toxicity Factor Value | Persistence Factor Value[a] | Bioaccumu-lation Factor Value[a] | Toxicity/Pers-istence/Bioa-ccumulation Value (Ref. 1; Table 4-16) | Page Number in Reference 2 |
|---|---|---|---|---|---|---|
| Antimony | 4 | 10,000 | 1 | 5 | $5 \times 10^4$ | BI-1 |
| Arsenic | 1, 3, 4 | 10,000 | 1 | 5 | $5 \times 10^4$ | BI-1 |
| Barium | 1, 3, 4, 5 | 10,000 | 1 | 500 | $5 \times 10^6$ | BI-1 |
| Beryllium | 4 | 10,000 | 1 | 50 | $5 \times 10^5$ | BI-2 |
| Cadmium | 3, 4, 5 | 10,000 | 1 | 5,000 | $5 \times 10^7$ | BI-2 |
| Chromium | 4, 5 | 10,000 | 1 | 500 | $5 \times 10^6$ | BI-3 |
| Cobalt | 4, 5 | 10 | 1 | 5,000 | $5 \times 10^4$ | BI-3 |
| Copper | 1, 3, 4, 5 | 0 | 1 | 500 | 0 | BI-3 |
| Lead | 1, 2, 3, 4, 5 | 10,000 | 1 | 5 | $5 \times 10^4$ | BI-8 |
| Manganese | 4, 5 | 10,000 | 1 | 50,000 | $5 \times 10^8$ | BI-8 |
| Mercury | 1, 2, 3 | 10,000 | 1 | 50,000 | $5 \times 10^8$ | BI-8 |
| Nickel | 4 | 10,000 | 1 | 0.5 | 5,000 | BI-9 |
| Selenium | 4, 5 | 100 | 1 | 50 | 5,000 | BI-10 |
| Zinc | 1, 3, 4, 5 | 10 | 1 | 5 | 50 | BI-12 |

a. River persistence value (Ref. 2).
b. Food chain bioaccumulation values for fresh water (Ref. 1, p. 51617; Ref. 2).

The hazardous substances having the highest Toxicity/Persistence/Bioaccumulation Value of $5 \times 10^8$ are manganese and mercury.

#### 4.1.3.2.2 Hazardous Waste Quantity

| Source Number | | Source Hazardous Waste Quantity Value [a] | Containment Value for Surface Water [b] |
|---|---|---|---|
| 1. | Formosa 1 Adit and Silver Butte Adit Waste Rock Piles | 3,040 | 10 |
| 2. | 404 Adit Waste Rock Pile | 8 | 10 |
| 3. | Encapsulation Mound | 10,606 | 10 |
| 4. | Formosa 1 Adit and Silver Butte Adit | 605 | 10 |
| 5. | 404 Adit | 0.288 | 10 |
| **Total** | | **14,259.288** | |

a. see Section 2.2 of this document.
b. Ref. 1, p. 51610, Table 4-2

A hazardous waste quantity factor value of 10,000 is assigned (Ref. 1, p. 51591).

Hazardous waste quantity factor value: 10,000
[Ref. 1, p. 51591 (Table 2-6)]

#### 4.1.3.2.3 Waste Characteristics Factor Category Value

Toxicity/persistence factor value x hazardous waste quantity factor value: $1 \times 10^8$ (Ref. 1, p. 51592)
$10,000 \times 10,000 = 1 \times 10^8$, capped at $1 \times 10^8$

(Toxicity/persistence x hazardous waste quantity) x food chain bioaccumulation factor value: $1 \times 10^{12}$ (Ref. 1, p. 51592)
$(1 \times 10^8) \times (5 \times 10^4) = 5 \times 10^{12}$, capped at $1 \times 10^{12}$

Hazardous Waste Quantity Factor Value: 10,000
Waste Characteristics Factor Category Value: 1,000
Ref. 1, p. 51592, Table 2-7

### 4.1.3.3 HUMAN FOOD CHAIN TARGETS
### 4.1.3.3.1 Food Chain Individual

Level I concentrations for the Human Food Chain Threat is not being evaluated.

Fishing on Cow Creek and its tributaries has been open since 2001 (Ref. 15, p. 1). Fishing on the tributaries of Cow Creek upstream of the Middle Creek Bridge (see Figure 4 and Ref. 15, p. 2 for bridge location) is open for trout fishing from May 27 to September 15, annually (Ref. 29, p. 3). Fishing on the mainstem Cow Creek from the mouth upstream to the Middle Creek Bridge is open for adipose fin-clipped steelhead from January 1 through April 30 and from December 1 through 31 and for trout from May 27 through September 15 (Ref. 29, p. 3). The Middle Creek Bridge is a popular fishing location (Ref. 15, p. 1). Although fish catch data are not maintained by the Oregon State Police, the Oregon State Police Game Officers have caught people fishing on Middle Creek outside of the permitted times (Ref. 31, p. 1). Based on chemical analysis (see Figures 2 through 4 and observed release by chemical analysis [section 4.1.2.1.1]), fishing is occurring in the zone of actual contamination and is subject to Level II concentrations.

A fishery within the TDL is subject to actual human food chain contamination because a hazardous substance with a bioaccumulation potential factor value of 500 or greater is present in a surface water sample from the watershed at a level that meets the criteria for an observed release to the watershed from the site, and at least a portion of the fishery is within the boundaries of the observed release (Ref. 1, p. 51620).

Food Chain Individual Factor Value: 45

#### 4.1.3.3.2 Population

4.1.3.3.2.1 Level I Concentrations

Not scored.

Level I Concentrations Factor Value: 0

4.1.3.3.2.2 Level II Concentrations

The Level II zone of contamination extends from the most upstream PPE to sample Cow Creek 2 (C2), which is the most downstream sample that meets observed release criteria (see Figure 4).

Juvenile salmonids were using Middle Creek for rearing in 1984 and 1988 before the Formosa Mine was re-opened (Ref. 22, p. 163). Data collected on Middle Creek and South Fork Middle Creek from 1982 through 1999 suggest that biological conditions have substantially degraded since the closure of the Formosa Mine (Ref. 5, p. 15). Data from a U.S. Forest Service investigation from 1982 to 1984 indicated that a steelhead fishery was present in Middle Creek (Ref. 6, p. 9). Further investigation by Formosa Exploration, Inc. in 1988 indicated relatively high densities of rainbow trout, steelhead trout, and Coho salmon juveniles (Ref. 6, p. 10). Prior to reclamation efforts, large numbers of Coho and rainbow trout were noted in Middle Creek and South Fork Middle Creek (Ref. 17, p. 2).

The releases by Formosa Exploration degraded the water quality and eliminated a fishery and the macroinvertebrates needed to support the fishery (Ref. 30, p. 2). Discharges from the Formosa Mine probably have been negatively affecting Middle Creek for approximately 80 years (Ref. 22, p. 18). A spill contaminated Middle Creek with an estimated 20 tons of pyrite and other metal-bearing sulfide minerals and was spread over about 4,000 feet of stream length (Ref. 22, p. 18). Small quantities of the material were visible one mile downstream and the creek was effectively "dead" with no signs of life farther down the stream (Ref. 22, p. 18). A fish survey in the summer of 1993 showed no fish in Middle Creek above the confluence with the South Fork of Middle Creek (Ref. 22, p. 18). The sulfides were removed from Middle Creek; but the process also removed all organic material from the stream bed which may have filtered metals from the stream (Ref. 22, p. 18).

An inspection by DOGAMI on March 14, 1994 detected no fish or aquatic insects in approximately two miles of stream between the end of the sulfide materials and where the South Fork of Middle Creek and Middle Creek join (Ref. 22, p. 18). Three dead fish were found fifty feet below the confluence of Middle Creek and South Fork Middle Creek on March 17, 1994 (Ref. 22, p. 18). In 2004, it was documented that heavy metals concentrations in Middle Creek and South Fork Middle Creek exceeded aquatic life standards by a factor of between 10 and 100, severely degrading habitat for aquatic receptors including macroinvertebrates, coastal steelhead trout, and Oregon coastal Coho salmon (Ref. 21, p. 1). In 2004, it was documented that the South Fork Middle Creek does not contain suitable habitat for fish (Ref. 19, p. 41). Table 17 below indicates historical presence of edible fish in South Fork Middle Creek and Middle Creek from 1969 through 2000. Lamprey, included in this table, is a traditional tribal fish used for consumption and in ceremonies (Ref. 32, p. 39).

| Table 17 Historical Presence of Edible Fish on Middle Creek and South Fork Middle Creek | | | | |
|---|---|---|---|---|
| **Stream Location[a]** | **Date Sampled** | **Species** | **Number** | **Reference** |
| South Fork Middle Creek M1.0 | 1988 | Rainbow trout | 7 | Ref. 20, p. 1, Ref. 26, pp. 1,6 |
| | | Coho | 13 | Ref. 20, p. 1, Ref. 26, pp. 1,6 |
| South Fork Middle Creek M1.7 | 1969 | Cutthroat | present | Ref. 24, pp. 1 and 17 |
| South Fork Middle Creek M3.0 | 1969 | Cutthroat | present | Ref. 24, pp. 1 and 16 |
| | | Steelhead | present | Ref. 24, pp. 1 and 16 |
| | 1982 | Coho | 2 | Ref. 25, p. 5 |
| | | Lamprey | 1 | Ref. 25, p. 5 |
| South Fork Middle Creek M4.7 | 1982 | Coho | 4 | Ref. 25, p. 5 |
| | | Lamprey | 2 | Ref. 25, p. 5 |
| | 2000 | Trout | 2 | Ref. 27, p. 2 |
| | | Steelhead | 4 | Ref. 27, p. 2 |
| Middle Creek M2.0 | 1969 | Cutthroat | present | Ref. 24, pp. 1 and 13 |
| | | Steelhead | present | Ref. 24, pp. 1 and 13 |
| | | Coho | present | Ref. 24, pp. 1 and 13 |
| Middle Creek M3.0 | 1982 | Cutthroat | 1 | Ref. 20, p. 1; Ref. 25, pp. 1, 2 |
| | 1984 | Coho | 5 | Ref. 20, p. 1; Ref. 25, pp. 1, 2 |
| | 1988 | Rainbow trout | 3 | Ref. 20, p. 1, Ref. 26, pp. 1,6 |
| | | Cutthroat | 1 | Ref. 20, p. 1, Ref. 26, pp. 1,6 |
| | | Coho | 25 | Ref. 20, p. 1, Ref. 26, pp. 1,6 |
| | 2000 | Coho | 1 | Ref. 27, p. 2 |
| Middle Creek M7.9 | 1969 | Squawfish | present | Ref. 24, pp. 1 and 7 |
| | | Coho | present | Ref. 24, pp. 1 and 7 |
| | | Cutthroat | present | Ref. 24, pp. 1 and 7 |
| | 1984 | Coho | 6 | Ref. 20, p. 1; Ref. 25, pp. 1, 3 |
| | 2000 | Trout | 25 | Ref. 27, p. 2 |
| | | Steelhead | 1 | Ref. 27, p. 2 |
| | | Coho | 2 | Ref. 27, p. 2 |
| Middle Creek M9.8 | 1969 | Squawfish | present | Ref. 24, pp. 1 and 5 |
| | 2000 | Trout | 23 | Ref. 27, p. 2 |
| | | Steelhead | 9 | Ref. 27, p. 2 |
| | | Cutthroat | 1 | Ref. 27, p. 2 |
| | | Coho | 3 | Ref. 27, p. 2 |
| Middle Creek M13 | 1969 | Coho | present | Ref. 24, pp. 1 and 2 |
| | | Steelhead | present | Ref. 24, pp. 1 and 2 |
| | | Squawfish | present | Ref. 24, pp. 1 and 2 |
| | 2000 | Trout | 6 | Ref. 27, p. 2 |
| | | Steelhead | 1 | Ref. 27, p. 2 |
| | | Coho | 17 | Ref. 27, p. 2 |
| | | Lamprey | 5 | Ref. 27, p. 2 |

Note: [a] Indicates the distance downstream from the mine.

A search of State of Oregon Department of Fish and Wildlife web site (Ref. 38) does not provide actual fish catch data for Middle Creek and South Fork Middle Creek; therefore as a conservative measure, it is assumed that greater than 0 fish which historically occurred in

Middle Creek and South Middle Creek were caught (Ref. 14, p. 2; Ref. 24, pp. 13, 16, 17; Ref. 25, pp. 1, 2, 3, 5, 6; Ref. 26, p. 6; Ref. 27, p. 2; Ref. 31, p. 1).

Based on information collected during a fish sampling event conducted by the U.S. Bureau of Land Management in May 2003, no fish were noted on South Fork Middle Creek at locations 1.7, 3.0, and 4.7 or on Middle Creek at location 2.0 (Ref. 28, pp. 2, 3, 4, 5).

Fishing on Cow Creek and its tributaries has been open since 2001 (Ref. 15, p. 1). Fishing on the tributaries of Cow Creek upstream of the Middle Creek Bridge (see Ref. 15, p. 2 for bridge location) is open for trout fishing from May 27 to September 15, annually (Ref. 29, p. 3). Fishing on the mainstem Cow Creek from the mouth upstream to the Middle Creek Bridge is open for adipose fin-clipped steelhead from January 1 through April 30 and from December 1 through 31 and for trout from May 27 through September 15 (Ref. 29, p. 3). The Middle Creek Bridge is a popular fishing location (Ref. 15, p. 1). Although fish catch data are not maintained by the Oregon State Police, the Oregon State Police Game Officers have caught people fishing on Middle Creek outside of the permitted times (Ref. 31, p. 1). Based on chemical analysis (see Figures 2 through 4), fishing is occurring in the zone of actual contamination and is subject to Level II concentrations (see Table 13) (Ref. 15, p. 1; Ref. 29, p. 3; Ref. 31, p. 1).

The assigned human food chain population value for greater than 0 to 100 pounds of fish is 0.03 [Ref. 1, p. 51621 (Table 4-18)].

Level II Concentrations Factor Value: 0.03

4.1.3.3.2.3 *Potential Human Food Chain Contamination*

The main stem of Cow Creek is a fishery (Ref. 18, p. 1). A search of State of Oregon Department of Fish and Wildlife web site (Ref. 38) does not provide actual fish catch data for Cow Creek; therefore, it is assumed that greater than 0 pound of fish is caught annually within the TDL.

The assigned Human Food Chain population value for 0 to 100 lbs of fish is 0.03 [Ref. 1, p. 51621 (Table 4-18)]. The average annual flow rate for 2003 for Cow Creek, as measured near Riddle, Oregon is 629 cfs (Ref. 13, p. 1). Riddle, Oregon is located 18 miles downstream of the confluence of Middle Creek and Cow Creek (Ref. 12, p. 3-3). The flow rate of Cow Creek is likely to vary between the end of the TDL and the measurement point at Riddle, Oregon. For this reason, a flow rate for Cow Creek of greater than 100 to 1,000 cfs will be used. The dilution weight for Cow Creek (a moderate to large stream) is 0.01 [Ref. 1, p. 51613 (Table 4-13)]. The potential targets value for the Human Food Chain Threat is calculated as follows (Ref. 1, pp. 51613 and 51621).

0:03 x 0.01 = 0.0003 / 10 = 0.00003

Potential Human Food Chain Contamination Factor Value: 0.00003

### 4.1.4.2 WASTE CHARACTERISTICS

#### 4.1.4.2.1 Ecosystem Toxicity/Persistence/Bioaccumulation

Table 18 below provides Environmental Threat Waste Characteristics Factor Values for those hazardous substances present in sources at the Formosa Mine (see Section 2.2).

**Table 18 Environmental Threat Waste Characteristics Factor Values**

| Hazardous Substance | Source | Ecosystem Toxicity Factor Value [a] | Persistence Factor Value [b] | Bioaccumulation Factor Value [c] | Ecosystem Toxicity/Persistence/Bioaccumulation Value (HRS Table 4-16) | Page Number in Reference 2 |
|---|---|---|---|---|---|---|
| Antimony | 4 | 100 | 1 | 5 | 500 | BI-1 |
| Arsenic | 1, 3, 4 | 10 | 1 | 5,000 | $5 \times 10^4$ | BI-1 |
| Barium | 1, 3, 4, 5 | 1 | 1 | 500 | 500 | BI-1 |
| Beryllium | 4 | 0 | 1 | 50 | 0 | BI-2 |
| Cadmium | 3, 4, 5 | 10,000 | 1 | 50,000 | $5 \times 10^8$ | BI-2 |
| Chromium | 4, 5 | 10,000 | 1 | 500 | $5 \times 10^6$ | BI-3 |
| Cobalt | 4, 5 | 0 | 1 | 5,000 | 0 | BI-3 |
| Copper | 1, 3, 4, 5 | 1,000 | 1 | 5,000 | $5 \times 10^6$ | BI-3 |
| Lead | 1, 2, 3, 4, 5 | 1,000 | 1 | 50,000 | $5 \times 10^7$ | BI-8 |
| Manganese | 4, 5 | 0 | 1 | 50,000 | 0 | BI-8 |
| Mercury | 1, 2, 3 | 10,000 | 1 | 50,000 | $5 \times 10^8$ | BI-8 |
| Nickel | 4 | 100 | 1 | 500 | $5 \times 10^4$ | BI-9 |
| Selenium | 4, 5 | 1,000 | 1 | 500 | $5 \times 10^5$ | BI-10 |
| Zinc | 1, 3, 4, 5 | 10 | 1 | 50,000 | $5 \times 10^5$ | BI-12 |

a. Fresh water values (Ref. 1, p. 51621; Ref. 2, pp. BI-1, BI-2, BI-3, BI-8, BI-9, BI-10, BI-12).

b. River persistence values (Ref. 2, pp. BI-1, BI-2, BI-3, BI-8, BI-9, BI-10, BI-12).

c. Fresh water values (Ref. 1, p. 51622; Ref. 2, pp. BI-1, BI-2, BI-3, BI-8, BI-9, BI-10, BI-12).

The hazardous substances having the highest Ecosystem Toxicity/Persistence/Bioaccumulation Factor value of $5 \times 10^8$ are cadmium and mercury.

Ecosystem Toxicity/Persistence/Bioaccumulation Factor Value: $5 \times 10^8$

#### 4.1.4.2.2 Hazardous Waste Quantity

| Source Number | | Source Hazardous Waste Quantity Value [a] | Containment Value for Surface Water [b] |
|---|---|---|---|
| 1. | Formosa 1 Adit and Silver Butte Adit Waste Rock Piles | 3,040 | 10 |
| 2. | 404 Adit Waste Rock Pile | 8 | 10 |
| 3. | Encapsulation Mound | 10,606 | 10 |
| 4. | Formosa 1 Adit and Silver Butte Adit | 605 | 10 |
| 5. | 404 Adit | 0.288 | 10 |
| **Total** | | **14,259.288** | |

a. see Section 2.2 of this document.
b. Ref. 1, p. 51610, Table 4-2

A hazardous waste quantity factor value of 10,000 is assigned (Ref. 1, p. 51592).

Hazardous waste quantity factor value: 10,000
[Ref. 1, p. 51591 (Table 2-6)]

#### 4.1.4.2.3 Waste Characteristics Factor Category Value

Ecosystem toxicity/persistence factor value x hazardous waste quantity factor value: $1 \times 10^8$ (Ref. 1, p. 51624)

$10{,}000 \times 10{,}000 = 1 \times 10^8$, capped at $1 \times 10^8$

(Ecosystem toxicity/persistence x hazardous waste quantity factor value) x ecosystem bioaccumulation potential factor value: $1 \times 10^{12}$ (Ref. 1, p. 51624)

$(1 \times 10^8) \times (50{,}000) = 5 \times 10^{12}$, capped at $1 \times 10^{12}$

Hazardous Waste Quantity Factor Value: 10,000
Waste Characteristics Factor Category Value: 1,000
Ref. 1, section 2.4.2.2, Table 2-7

#### 4.1.4.3 ENVIRONMENTAL THREAT – TARGETS

Level I concentrations for the Environmental Threat are not being scored.

##### 4.1.4.3.1 Sensitive Environments

##### 4.1.4.3.1.1 Level I Concentrations

Sensitive Environments

Not scored.

Wetlands

Not scored.

Level I Concentrations Factor Value: 0

#### 4.1.4.3.1.2 Level II Concentrations

Sensitive Environments

Middle Creek is designated as a Tier 1 Key Watershed under the Northwest Forest Plan (Ref. 6, p. 7; Ref. 33, p. 2). A Tier 1 Key Watershed serves as refugia crucial for maintaining and recovering habitat for at-risk stocks of anadromous salmonids and resident fish species (Ref. 33, p. 2). Once restored, Middle Creek would act as a migratory pathway and feeding area critical for the maintenance of anadromous fish species within this river reach in which the fish would spend extended periods of time (Ref. 33, p. 2). Table 19 provides a summary of sensitive environments subject to Level II concentrations (Ref. 1, p. 51624 [Table 4-23]).

**Table 19 Sensitive Environments Subject to Level II Concentrations**

| Sensitive Environment | Location | Reference | Sensitive Environment Value (Ref. 1, p. 51624, [Table 4-23]) |
|---|---|---|---|
| Migratory pathway and feeding area critical for maintenance of anadromous fish species within river reaches in which the fish spend extended periods of time. | Middle Creek | Ref. 33, p. 2 | 75 |

Sum of Sensitive Environment Value: 75

Wetlands

Not scored.

Sum of Wetlands Value [Ref. 1, p. 51625 (Table 4-24)]: 0

Sensitive environment value + Level II wetland value: 75

Level II Concentration Factor Value: 75

#### 4.1.4.3.1.3 Potential Contamination

Sensitive Environments

Sum of Sensitive Environment Value:

Wetlands

Not scored.

Sum of Wetlands Value [Ref. 1, p. 51625 (Table 4-24)]: 0

Potential Contamination Factor Value: 0